HARMSWORTH POPULAR SCIENCE

EDITED BY ARTHUR MEE

CONTRIBUTING STAFF

ON THE CONTRIBUTING AND CONSULTING STAFF OF POPULAR SCIENCE ARE

CALEB WILLIAMS SALEEBY
Fellow of the Royal Society of Edinburgh, Doctor of Medicine, Scientific Author, Lecturer at the Royal Institution

L. G. CHIOZZA MONEY, M.P.
Author and Political Economist

W. BEACH THOMAS
Journalist and Agricultural Expert.

JOHN DERRY
Journalist and Educationalist

EDWARD WRIGHT
Writer on Philosophy

GERALD LEIGHTON
Professor of Pathology and Bacteriology at Edinburgh University

J. THORNE BAKER
Electrical Expert, Lecturer at the Royal Institution

HAMILTON FYFE
Author and Journalist.

ERNEST A. BRYANT
Author of the Natural History section of the Children's Encyclopædia

RONALD CAMPBELL MACFIE, M.A.
Author of "Science, Matter, and Immortality"

JOSEPH HORNER
Author of technical works, member of the Institute of Mechanical Engineers

AND OTHERS

***

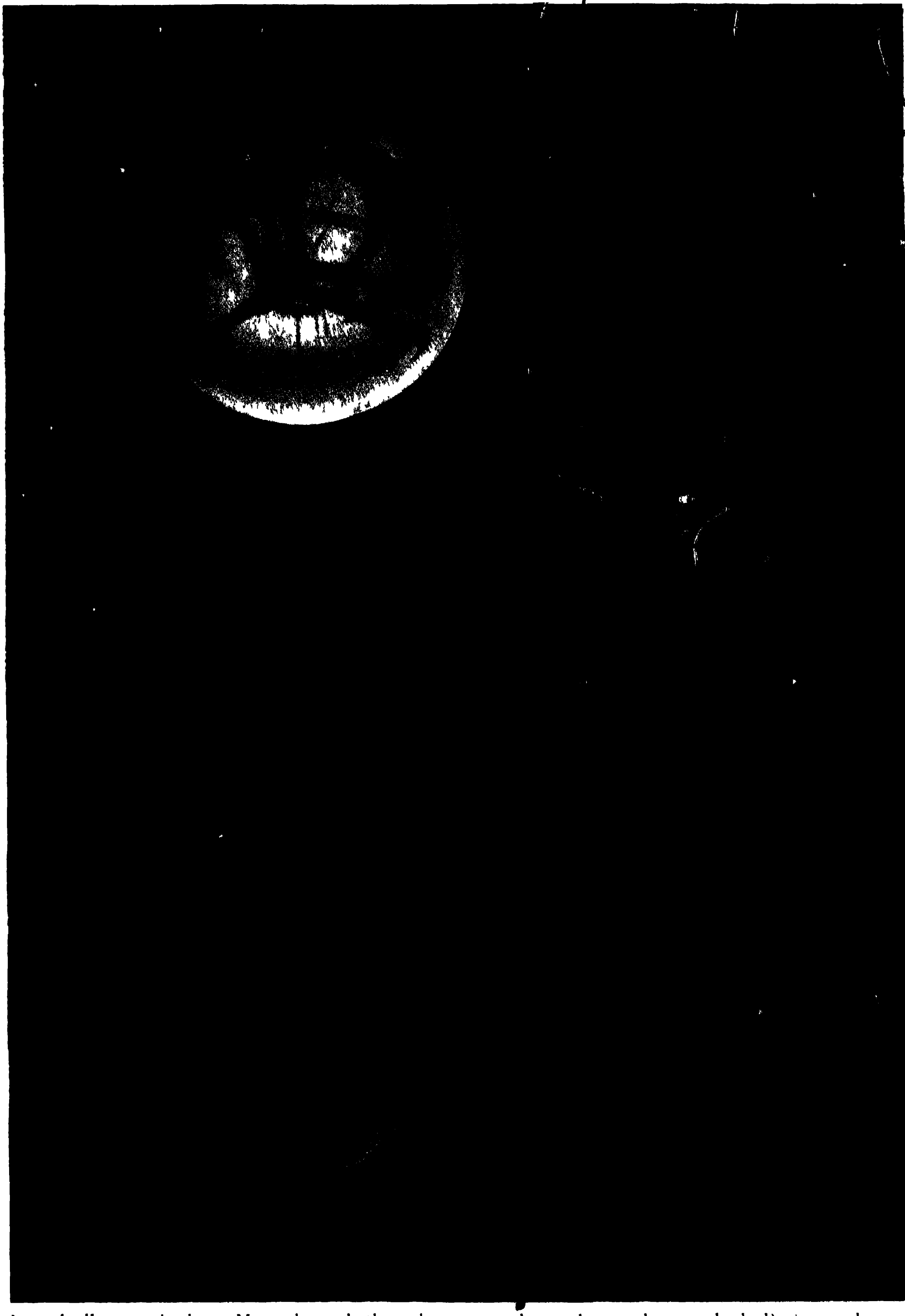
1902.

LONDON:

THE EDUCATIONAL BOOK CO., LTD.

THE CONQUEROR OF THE EARTH—WILL HE MASTER THE SUN?

HAS MAN A BROTHER IN THE SKIES?



It is thrilling to look at Mars through the telescope and see the markings which Professor Lowell says are canals made by living hands. Science has not yet accepted this view, but if it is true it means that these canals are the only mark we know in the heavens not made by the hand of God.

THE STORY OF THIS BOOK

BY ARTHUR MEE

This book is the story of Man and the World. It tells the history of the earth and the life of man. It goes back, as clearly as the mind of man can, to the days when the iron with which we build our ships poured down on the earth as red-hot rain; it describes, as plainly as the words of men can, the things that men are doing on the earth to-day; it looks forward, as hopefully as the faith of man can, to the destiny that awaits the human race. It is the book of Time and Space and all things in them, embraced in twelve great divisions, which are here described.

GROUP 1
THE UNIVERSE

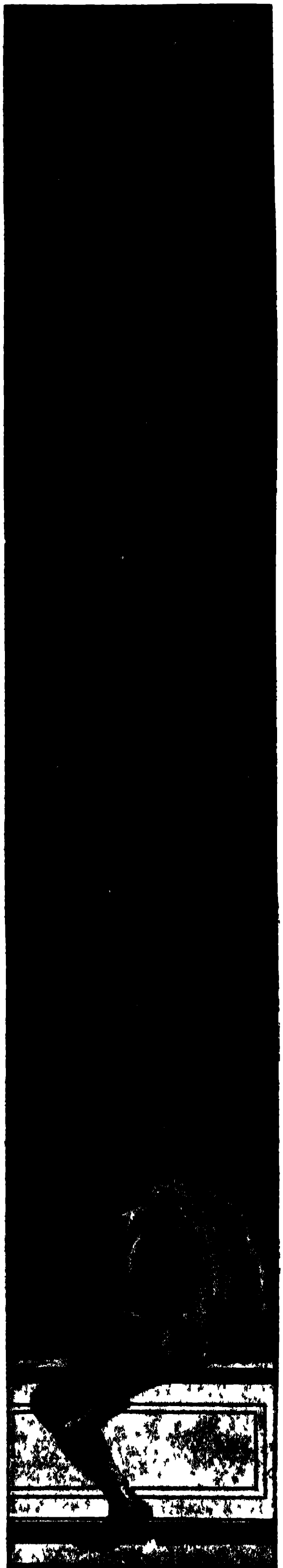
The Making of Worlds

Millions of worlds fly about in space, and we live on one of them. Millions of stars shine through the skies, and all the stars are suns. You who read are one of millions of living things on one of millions of flying worlds. What is behind them all—at the back of what we call Space, before the beginning of what we call Time? This giant sun, with heat enough to give to every human being on the earth as much as he gives to the whole earth itself, yet small enough to be the least of all the suns there are—what is the mighty scheme in which his part is but a little thing? What are these other worlds to us, and we to them? Are they alive? *Can they be dead?* Are they before us, or behind us, in the unfolding of Creation? We talk of power; but what of the power which swings these worlds in space, some of them on fire, some of them so far away that the mind of man cannot conceive the distance, some of them with raging seas of red-hot iron, most of them bigger than our own world, which seems to overwhelm us, yet is like a grain of sand in the vastness of the universe! What was the beginning? What is the end?

GROUP 2
THE EARTH

The Earth we Live on

Out of the Everywhere came a million worlds; out of a cloud of fire came the earth on which we live. Countless journeys the cloud of fire made through the heavens before the red-hot earth cooled down, shrank within itself, threw off the fragment that is now our moon, and became a mighty ball 8,000 miles from side to side and 25,000 miles round. So huge a thing to us that the mind cannot conceive it, this earth is but a speck among the worlds that whirl with it in space, and on this speck, this atom in a universe, roll the Atlantic Ocean and the great Pacific. Out of this speck rise all the powers that men control; on this speck happened all that history has to tell. From inside



this little ball comes all the iron of which our ships are made, all the stone with which we build, all the gold for which we crave. Round about this globe, above and below and on every side, roll invisible oceans—of air that gives us life, of force that drives our wheels, of waves that carry our words as if on wings. This is the story of the making and the shaping of the earth and the waters of the earth, of the forces which spring from the earth, and the things of which the earth is made. It is the story of our home, of what we mostly mean by Nature—that Nature which, in a few short ages only, men have learned to command, in Bacon's words, by learning to obey her.

GROUP 3
LIFE

Life Takes Possession

For ages our red-hot earth swung round in space. Its fires cooled down; the seas were formed; and there came into the sea one day what was, so far as we know, the only thing in all these worlds that moved of itself. Life grew up in the waters and crept ashore, and on land life grew until, in its strength, it took possession of the earth. For millions of years life built up for itself millions of homes—plant homes, keeping to the place where they were built, and animal homes, moving from place to place. For millions of years life crept into things of all sorts and shapes—hideous, beautiful, monstrous, small, creeping, flying, crawling, walking, swimming; rising from the earth like an oak, dancing in the air like a gnat, crashing through the forest like a mastodon, creeping in the grass like a snake, bursting from the bud like a rose, rising to the sky like a lark, singing like a nightingale, roaring like a lion. Like a wave life swept across the earth, until sky and sea, and mountain and valley and plain, became the home of millions of incredible things, living and dying and giving new life to their kind. Then came a living thing that could speak and think and act and know itself, and at last Man was upon the earth, an insignificant creature, surrounded with wild beasts many times his size, and with many times his power.

GROUP 4
PLANT LIFE

The Earth Alive

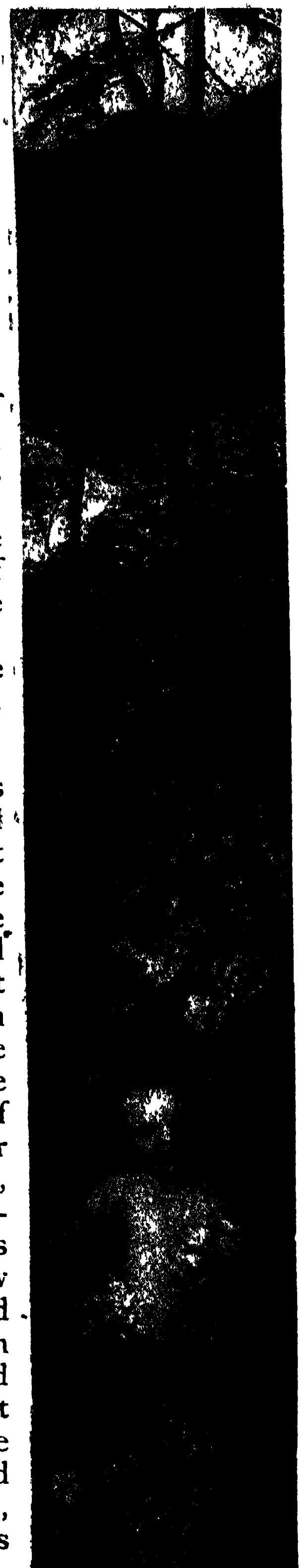
Life covered the earth At first, perhaps, it was movement. Perhaps the first living thing was just a creature that could move itself. And then all things seemed to feel the thrill of life. Over the surface of the earth was spread a wonderful carpet, a thing of colour and beauty that repaired and renewed itself, a universal living garment woven by the Hand that made the

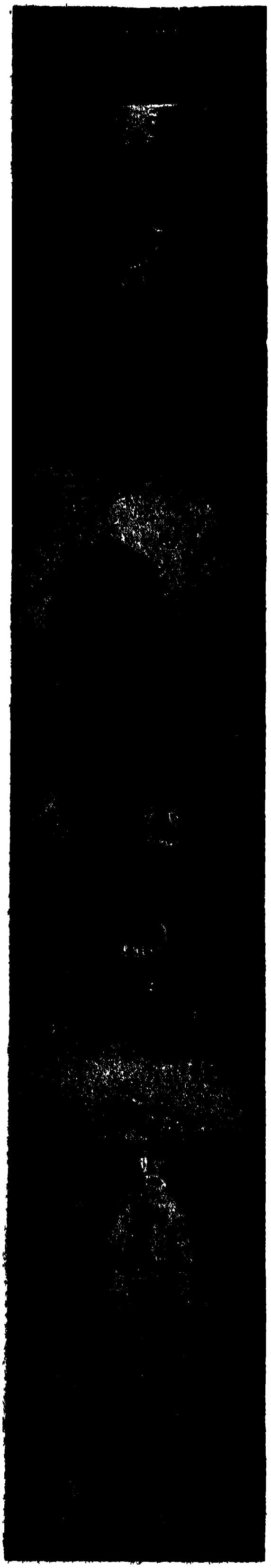
heavens. Except in the crater of some volcano, or on the very edge of the rolling sea, or at the top and bottom of the revolving sphere where the waters were frozen white and still, there was hardly a spot on all the earth where this carpet did not spread. And for age after age the hand of the Weaver went on, giving the carpet colours wondrous to behold, and power to reproduce itself and to grow more wondrous still, until it assumed at last a million million forms, which became, under the controlling hand of man, with the co-operation of sun and wind and rain, not only the glory of the earth, but the upholder of the human race itself. Out of the earth come life and strength for all that live upon it. Out of an acorn comes an oak; from a seed in a child's hand may come a mighty forest. Food for man to eat, clothes for man to wear, wood for man to build his houses with, come silently out of the earth each year. This is the story of the living carpet that covers the earth, of the beautiful garden, and the wheat-field, and the mighty forest, and the woods that are lovely to walk in, and of all the growing things about us, which are together at once the wonder and sustainer of mankind.

GROUP 5
ANIMAL LIFE

The Forerunners of Man

Life, which brings forth the beauty of a red rose, brings forth, too, the music of the nightingale and the terror of a roaring lion. Greater in number than the stars that the naked eye can see is the variety of animals that make up dumb creation. An incredible pageant it would be could it pass before our eyes, this strange and fearful host that keeps man company on the earth. As different as a lark is from a serpent, as different as a bee is from a whale, as different as a horse is from a ladybird, the same life beats in all—the life that is in the wolf and in the little child. Masters of the early world, the forerunners of the human race, these lords of creation surrendered their lordship to man. With strength almost unimaginable, with cunning such as man can barely conceive, with endurance unmatched in any human being, the forerunners of man have succumbed to the only animal that can throw a stone. What, we may wonder, would have happened if man had remained a creature with four feet, or if man had never been? Would the ant then have controlled the world? It is one of the enthralling themes that come up in the story of the animal kingdom. Here the wonderful tale is told—the story of the life of all created things that live and move upon the earth, except Man, who has subdued them to his will, chained them to his service, won for himself even their friendship and devotion.





GROUP 6
MAN

Man Appears

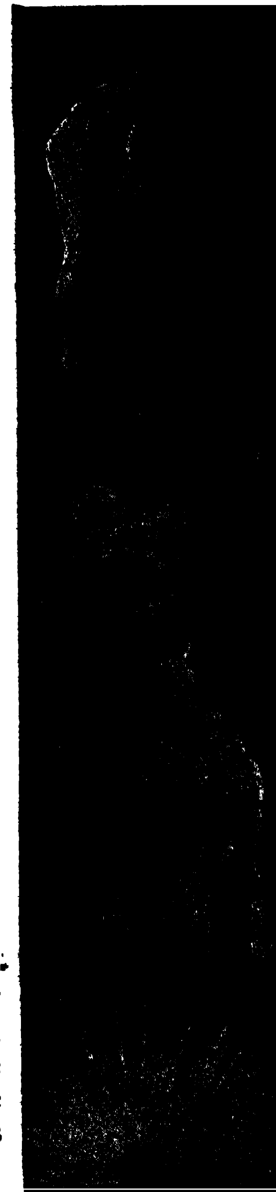
This little man, according to all the laws of chance, should have been gobbled up by a tiger or crushed by a mastodon, and have disappeared for ever off the earth. But man beat the mastodon, and set out for the mastery of the world. He found fire and heat. He made a boat and began to travel. He found something growing out of the earth and started agriculture. He measured time by the sun, and invented language. He collected himself into tribes, laying the foundation of races and nations ; and slowly there came to him the feeling that the world is not all mechanical, but that men are surrounded by powers that we cannot fathom. He explored the whole of this world and studied other worlds. He has been down in the earth, up in the air, and has walked along the bed of the sea. He has risen above the clouds and seen what is there. All this he has done—man, the king of animals—by virtue of something that no other animal has. Man is master of the earth, and Mind is the master of man. Here we read the incredible story of a man's brain, the grey matter that thinks out pictures and books and revolutions and Acts of Parliament and wars ; that draws intelligence from other worlds ; that weighs the earth and measures the sun—yet cannot understand itself. Is it merely matter, or more than matter? How does it know, and remember? Has this mind lived before, as heredity seems to suggest ; and does it go on for ever, as immortality implies?

GROUP 7
HEALTH

Man Builds up Strength

Here comes upon the scene our doctor, who lives to keep us well. We are made to be healthy, and there is no reason why we should be ill—no reason, that is, apart from ignorance, and dirt, and the bad ordering of our lives. While this paragraph is being written the life of some loved one in three hundred thousand homes is passing slowly away, from an illness which could not exist if each of us knew the rules of health as well as a schoolboy knows the rules of cricket. We live in a world of invisible powers, unseen but understood, affecting our lives from the cradle to the grave. Yet millions give less thought to these things than to a game, and in this busy world we have little time, perhaps, to think of ourselves. Here our doctor tells us how to live well—the sort of house we should live in ; the truth about rest and work and play ; the value of air and water and sun ; what we shall eat, what we shall drink, and wherewithal we shall be clothed. We shall

learn that health is ease in mind and body too. We shall learn the wisdom of Solomon, that "a merry heart doeth good like a medicine, but a broken spirit drieth the bone." We shall learn the wisdom of the dictionary, that healthy and happy and holy are three words with but one meaning. There is no wealth but health, and here is health for all, the plain rules of a game in which the loser is disease and the winner is a healthy man, a healthy woman, whole of body and whole of mind.



GROUP 8
POWER

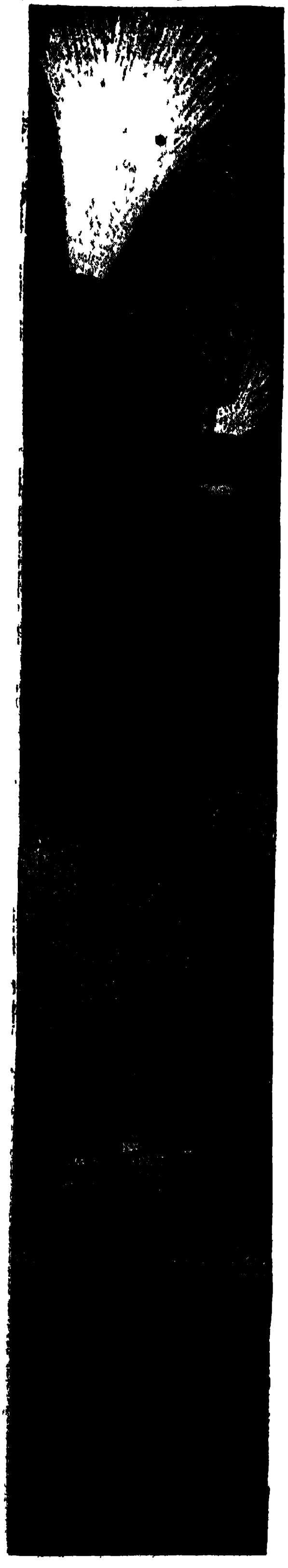
Man Finds Power

Man has to-day a million times the power he had a thousand years ago, power won from Nature, snatched from wind and river and sun. He is taking hold of the invisible powers of the world. He is harnessing natural forces to do the work his own hand cannot do. Here is told the story of power from the beginning, with all the marvellous means by which man, when he finds a thing impossible, makes a machine to do it. He sends his messages through air; he hitches his engines to the rivers; he floods the dark world with light drawn from beyond the ether. Man, in truth, is getting beyond his senses. Shakespeare put a girdle round the earth in forty minutes; man can do it now in four. Man can photograph a thing he cannot see; he can magnify sight and speech, and can store up sound. He can run like a deer, can fly like a bird, can swim like a fish; but he can do more, for he can travel faster than a bird, by a power that he can stop with his finger, and he can cross the earth without losing touch of home. From mid-air and mid-ocean too, from down in the earth and down in the sea, he sends his message where he will. The time will come when man will lengthen life, but while that day waits he abolishes space and time and magnifies the work that he may do in his allotted span

GROUP 9
INDUSTRY

Man Uses Power

The world's workshop is the world itself, and the workers are the human race. What are they doing? Millions are making ships and guns; millions are making and managing railways; millions are tilling the ground. Some are making a channel to join two oceans; some are boring a hole through the Alps; some are throwing huge bridges across wide rivers; some are stretching a telegraph wire across the desert. Some are digging up the old world; some are laying the foundations of new Babylons on the site of old-world empires. Some are blasting iron and making steel; some are printing papers and



books and covering the earth with the knowledge that man has won from darkness. Here we meet the great industrial armies of the world. We see them moving in masses to forward the comfort and unity and prosperity of mankind. We see the life of our factories and fields and mines. We have passing before us a panorama of the workshops of this busy world, a world alive with energy, creating, constructing, discovering, inventing, down-throwing, up-building, advancing for ever from conquest to conquest, from achievement to achievement, until the whole man-made world is changed and made anew.

GROUP 10
COMMERCE

Man Buys and Sells

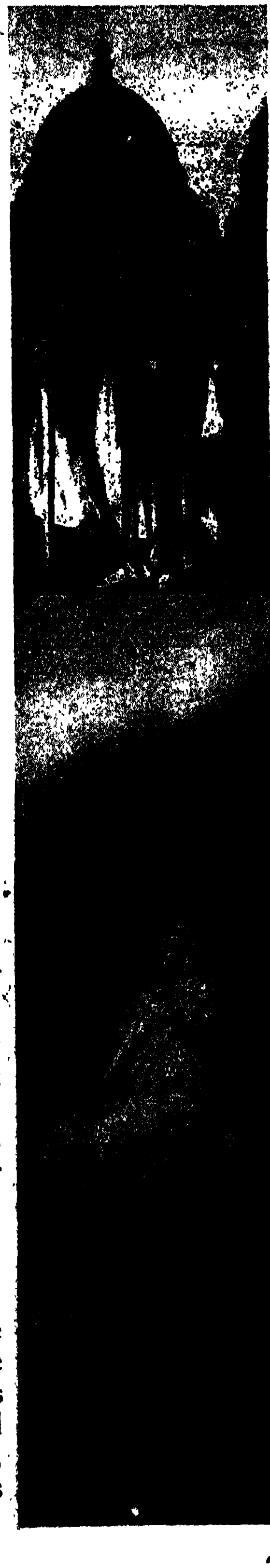
All the world buys and all the world sells. Here we come into the world's market-place, where America is selling cotton, and India is selling jute, and China is selling tea, and Persia is selling rugs, and Germany is selling dyes, and Japan is selling porcelain, and England is selling machines to all the world. How can we buy things we never touch, from men we never see, with money that does not exist? The commerce of Great Britain is the wonder of the world, yet there is not enough money in England to pay for one month's purchases. What is this wonderful machine that no man ever sees, controlled by ten thousand men in ten thousand places, which brings what we want from the ends of the earth and takes what we make in exchange? How is it that there comes to your door just what you want, at just the price you can afford to pay for it? The first men traded with bits of stick, now we trade with bits of paper: surely a simple change, yet bridging a gulf, from the stick to the paper, as wide as that which separates the modern Englishman from the men who lived in caves. This is the story of the meaning of money and the power of it, of trading and carrying, of saving and spending, of the whole working of the system—represented by the sovereign in your pocket—which binds the world together in an unbreakable chain, and may one day bind the world together in an unbreakable peace.

GROUP 11
SOCIETY

Man Organises Society

Man was not made to live alone. Far back in the days of the great Cave Bear men came together in groups and gathered together in tribes, and slowly there dawned on the minds of men a primitive vision of society. From chaos to a sort of order, from a sort of order to the beginning of law, mankind emerged while the soul of man was still lost in a darkness that no light could

penetrate, in a depth of ignorance and bewilderment that no intelligence could fathom. And step by step, through generations without number, the groups and tribes and races of mankind became the founders of the nations of the world to-day. This is the story of the building up of civilisation from barbarism. To you who read it, it is the story of your family, of the accumulated wisdom and untiring energy of a thousand years of men which lie behind the happy home, the quiet street, the prosperous city, the united nation. It is the story of how millions of men, each with his own interest, his own ambition, his own selfishness, live together at peace with all for the good of all. It is a long, long look through the ages of Time, from the days when men fought the mammoth for the mastery of the earth to the coming days of the Golden Age—



When the war-drum throbs no longer, and the battle-flags are furled,
In the Parliament of Man, the Federation of the World.

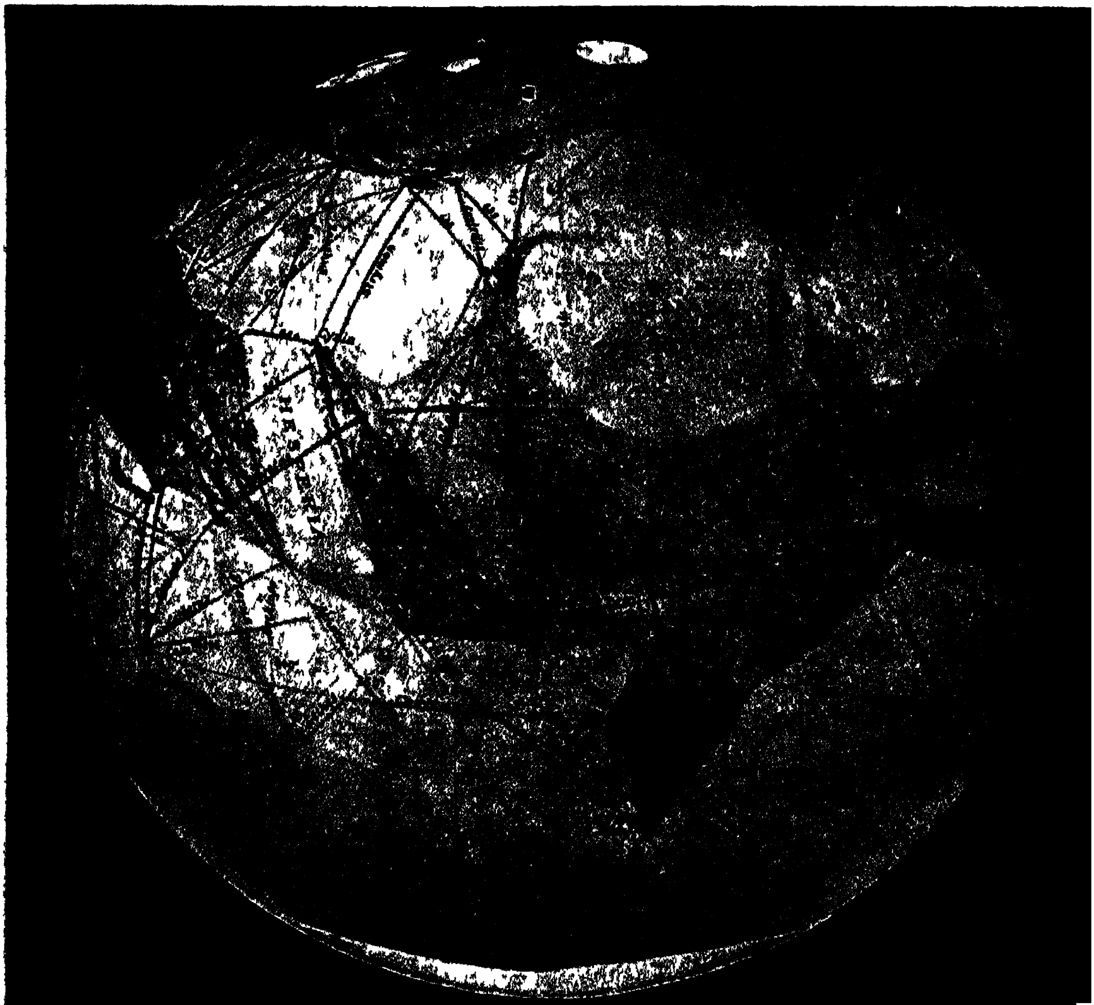
GROUP 12
EUGENICS

Man Creates the Future

In the people called Eugenists, in the faith that they hold, lies the hope of the world for the children of our children. Every man is part of the world; it is for every man to see that his part of the world is as good as it can be. That is the foundation of the youngest and greatest of all the sciences—Eugenics, the science of ennobling human life. We live not only to study the Past, not only to share in the Present, but to help to make the Future too. Society has three tenses. It is, in the fine thought of Edmund Burke, a partnership between all those who have lived, all those who do live, and all those who will live. All that is best from yesterday we of to-day must pass on for to-morrow. All that we owe to the past of the world we must pay back to the future of the world. Strength of limb and depth of mind we must give to our children; a great vision and a clear purpose; pleasant homes to live in, with the wind blowing round them and the sunlight dancing on the window; beautiful streets to walk in and healthy places to work in; manly labour for manly men and home-making for womanly women. We must give our children a noble ancestry to emulate, a noble vision to advocate, a noble offspring to anticipate. For these things we *do* hand down to unborn ages. No more is it said that the mind of a child is like a sheet of white paper, waiting for Time alone to write upon it, for we know from Heredity that the past also has written upon it with invisible ink which the future will reveal. Here we read of the betterment of human life, and of the way that leads from the land of our fathers to the land of our children, through the Gates of Dawn.

SIGNS OF POSSIBLE LIFE ON MARS

CHANGES ON MARS IN ONE MONTH, SUPPOSED TO BE DUE TO CLOUDS, AND THEREFORE TO WATER



MARS AS IT APPEARS THROUGH THE GREAT TELESCOPE AT FLAGSTAFF OBSERVATORY

MELTING SNOW ON MARS, AND THE APPEARANCE OF DARK AREAS SUPPOSED TO BE VEGETATION

The changes observed in the bottom picture were spread over five months, and Professor Lowell declares them to be due to the melting of snow and the running of the water down the canals, causing vegetation.

ARE WE ALONE IN THE UNIVERSE?

Millions of Other Worlds than Ours—Has Man a Companion in his Journey through the Heavens?

MARS FROM THE WATCH-TOWER IN ARIZONA

FROM the point of view of man's eyes, unaided by his mind's eye, nothing could be more evident, daily and nightly demonstrated, than that this earth of ours is the centre, the be-all and end-all, of things, having a greater light to rule the day, and a lesser light to rule the night, these and all other bodies in the sky being its satellites. The earth, then, is incomparable; there is and could be nothing like it; all else exists to serve it, and moves in humble order around its stable majesty. No possibility is here for the idea of a universe.

Only very few and scattered thinkers, probably less than half a dozen, arose to question this oldest and most obvious of theories, until one, Koppernik, a Northern monk, demonstrated that, notwithstanding the clear evidence of the eye, which sees the sun and moon and stars rise and set around this motionless earth, appearances are deceptive; that it is the earth which moves, nor is it the centre of all things. Not much later, in 1600, Giordano Bruno was burnt in Rome for arguing that, if the earth be not the centre of all things, it must then rather be one of a company of worlds, among which earth may not even be the greatest; and even that the sun, which Koppernik, or Copernicus, regarded as the centre of things, may be one of a company of suns, which men call the stars.

Thus first was the idea of a universe, a company of worlds, given form and substance, proclaimed before mankind, branded for a scurrilous and blasphemous lie, and its herald for one so foul that the company of men must rid itself by fire of such contamination. "And so," wrote one of his murderers, "he perished miserably in the flames, and in those other worlds which he imagined he can narrate how the Romans are wont to treat such blasphemous and profligate folk as himself."

Little more than three centuries later Bruno's idea has become a commonplace, which none are found to question. We admit it to be not merely true, but among the few most glorious and stupendous, most awe-inspiring and ennobling, of truths ever discerned by the mind of man; and a statue to Bruno stands upon the spot where his judicial murder was accomplished. It is now our concern to readjust our notions of ourselves and our earth, our importance, and our destiny, to this idea of the universe, which we must perforce accept; nor is it possible for us to make this attempt without asking and attempting to answer some of the most fascinating and mind-widening questions which present themselves when we learn that these bright spots in the sky are mostly suns like our sun, and some of them worlds like our earth.

Man, then, in his tremendous expedition through the ocean of the universe, whence he knows not, whither he knows not, may not be uncompanioned. If other worlds, why not other wayfarers? If he can hail other sails than his, why not other sailors? Bruno asked these questions, and had little doubt of the answers; and all men said the impious wretch must die. In the history of the sky, or of man, or even of modern civilisation, this was only yesterday; and to-day we all ask this question, and many men, in all quarters of the earth, devote their lives, and mighty resources of money and science, to answering them.

No one now supposes that the discoveries and speculations of astronomers are to be feared for their influence upon religion; but it is worth while, perhaps, to consider an argument which is heard still to-day. It is said that the effect of these studies,

and especially of such ideas as Bruno's, must be either to make men despise themselves, to hold life cheap, puny, and futile, or to terrify them with the thought that there is no help for them in the sky; and, indeed, that to think rightly of the universe is to be overwhelmed by the thought of it.

But, indeed, it is not so. "Let your soul stand cool and composed before a million universes," says Walt Whitman; and not only does the general common sense of man agree with him, but the experience of those who dwell nightly with the stars, those who study and speculate and constantly think of these things, is that his advice is not difficult to follow. "In the world there is nothing great but man, and in man there is nothing great but mind." Man's mind is not long daunted by any considerations of time and space and number—not even if their measure be infinity, as astronomy asserts. Horace declared that if the heavens were broken and fell upon the just man they would find him undismayed. In less speculative vein we may argue that life and death and love will always be nearer than the stars to "men's business and bosoms," and it is a poor and purblind philosophy which supposes that only in the heavens are infinite things.

COPERNICUS, THE FIRST MAN TO SAY 'THE EARTH MOVES

That the sun is a star, and the stars are suns, we know. That the earth is one of a company of planets, such as Mars, some nearer to, some farther from, our common sun, we know, and that these are themselves not luminous, but shine by reflected sunlight, we also know. The idea of a universe is established. But no man can think so far without asking questions which as yet science cannot answer.

Yet though no man can positively say, nor any deny, that life and mind are borne on other worlds, there is much evidence and much fruit for thought which will prepare our posterity to answer this question; and since we have gone so far already into the idea of the universe as a company of worlds, we may now consider the question whether each—or any but ours—of these worlds bears its company of living, and even of thinking, beings.

That such a thing could be, has been, and still is, most strenuously and indignantly denied by a few thinkers, who base their argument upon a gigantic misconception—a misconception which is fundamental to our subject and is shared not only by the uninitiate at large, but by many astronomers whose study has never been directed to the problems of terrestrial life. This misconception is that what we must look for in the heavens, and what alone we can expect to find, if we find anything, is man. For the moment we may ignore the possibility of, say, lowly vegetable life; it is the existence of a thinking, feeling being such as ourselves, elsewhere than on our earth, that matters for our idea of a universe now.

Nothing is easier to prove than that man could not exist upon Mars or Venus or Jupiter; and to those whose ideas of a thinking and feeling being cannot escape from themselves this is final; there are no men on Mars, and the discussion is closed. Many distinguished astronomers, including at least one contemporary of the first magnitude, have triumphantly come to this conclusion.

The student of life could not well have begun to discuss the question at all; and the conclusion is to him self-evident and necessary, and irrelevant. He was not looking for man, the child of earth, on any globe but earth. If the astronomers find in the sky, and report to the biologists, a sphere which is the exact or almost exact replica of earth—and not only so, but of earth during the recent millions of years of man's habitation—a sphere which is encompassed with an atmosphere of the same composition, pressure, and temperature, has oceans of the same saltness, microbes of the same species, clay of the same constitution, and receives light of the same quality and intensity, not to mention a thousand other essential details—then, and only then, will the student of life upon the earth expect to find similar forms of life, high and low, repeated in the sky.

We may even go farther, and say that if the astronomers should find an earth exactly like ours in all physical respects, it would *necessarily* be inhabited by living forms, from microbe to man, identical with those of our planet. And the biologist will go on to say that, in whatever degree or respect a celestial body differs from the earth—in being heavier or lighter, warmer or colder, brighter or darker, or what not—so its life, if it bears any, will also differ

from ours; its "microbes" will not be our microbes, nor its "men" our men.

For the biologist knows that man is minutely, incredibly, yet necessarily adapted to the home which bore him, and to the number and powers—for and against him—of all its other inhabitants.

No heavenly body we can observe could possibly harbour a human being, unless all biology and all common sense are mythical; no human being could possibly have been evolved except upon our planet, with its origin and its known history.

But then we may proceed, clear-headed, to ask whether there are heavenly bodies which might support *any* form of life, whether there is evidence that life does exist thereon, and whether that life, in any instance, displays qualities of mind which bring it into communion with our own, whether as an equal or in some such relation as that of a man to a dog—or a dog to a man.

Of course, there is nothing, if we be unprepared by sound ideas of chemistry and physics, and by wide and starry conceptions of the universal reign of Nature's laws, to deter us from supposing that life might exist upon the sun, or upon some waterless planet, or some airless planet, or in the absence of carbon and nitrogen. We may suppose, if we please, that the laws of chemistry, as we observe them on the earth, are only local and terrestrial; that living things, somewhere else, could derive energy from nowhere without the necessity of obtaining it by combustion; and that therefore the presence of oxygen is no necessity for life. Or we may suppose, if we will, that though living beings have to recognise and adapt themselves to the law of gravitation here, this law would not apply in Mars or Jupiter, and therefore that their differences in mass, which would greatly alter the conditions of existence if gravitation obtained on those planets, would not matter.

BRUNO, WHO WAS BURNT FOR SAYING THERE ARE OTHER WORLDS THAN OURS

So to suppose is to abandon science altogether; it is even to throw over the idea of a universe just when we are seeking to establish it. On the contrary, as we shall learn, the laws of Nature are uniform and universal, otherwise the universe would be no universe. Gravitation does act on Mars; carbon, oxygen, and hydrogen are carbon, oxygen, and hydrogen, whether they be terrestrial or Martian; and the laws of their combination, and of the consequent production of energy, are the same everywhere. Thus we are not entitled by science to any fantastic imaginings. We may imagine what we will; but the scientific imagination must be disciplined and determined by what science discerns and dictates.

Our problem is to ascertain the conditions of possible life, say, on the all but waterless surface of Mars, just as we endeavour to ascertain them in the watery but almost airless depths of the Pacific; and thereafter to consider what modes or forms of life could conceivably occur, according to our experience and knowledge of life here, in the particular conditions which we discover on Mars or any other celestial globe.

Thus we may imagine—or imagine that we imagine—life without water, but no man of science could take any pleasure in such imaginings. He knows that all terrestrial life is lived in water, that it is "an aquatic phenomenon," and when he studies the details of the process, so far as he can, it is to find that the chemical changes upon which life depends could not proceed in the absence of water—nay, more, of liquid water; for neither ice nor water-vapour will suffice. The student who argues that therefore no life could anywhere exist in the absence of water is hasty and illogical, for there might be conditions, unimaginable to him, in which life might dispense with water. But just because they are unimaginable to him, he makes formal acknowledgment of the possibility, and then dismisses it from his mind, which has better things to do. If the sky should fall, we should catch larks; if pigs had wings they could fly; granted. And now let us turn to what gives our minds more satisfaction.

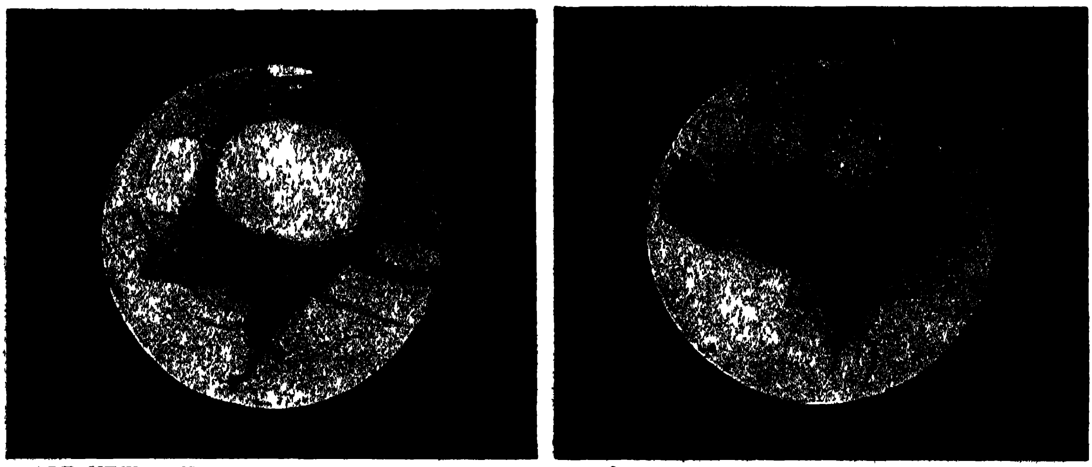
But now let the astronomer inform the student of life that he has definite evidence of water, say, upon Mars, and he will be agog in a moment, saying to himself: "Water! Indeed!" And then turning, as

quick as his thought, with the question: "And what about oxygen?" Given these and more conditions, and the student of life can imagine life wherever they obtain; and if life, why not mind?

Our inquiry may at last proceed. We know what we must reasonably look for, what conditions we must reasonably demand. They must suffice for life as we can conceive it, but assuredly they need not suffice for the maintenance of the particular kind of life which we call man. And if it should chance that not only are the minimum conditions discoverable, but also that there is *direct* evidence of life, and even of mind, as seen by their effects—somewhat like Man Friday's footprints, or the eagle feather of Browning's poem on Shelley, or the watch which Paley imagined to be found on a lonely heath—then we may count ourselves rewarded indeed.

The student who desires a definite and final answer to these questions will be disappointed: alike he who would fain suppose that man has no compeer nor parallel, much less superior, anywhere in boundless space, and he who would fain see life and love and genius possibly or actually sprouting in a thousand or a billion vessels throughout the universe. Few, perhaps, could belong to the first group who had read the noble sentences of Giordano Bruno; but our business three hundred years later, when we may believe what we will, and fear no stake, is not to follow our inclination, but to do our duty to the truth as Bruno did his, weighing the evidence impartially, and suspending judgment if need be.

The controversy at the present time centres, naturally enough, upon our nearest planetary neighbours in space. Our own moon, of course, is very much nearer, and can be much more minutely studied; nor are there astronomers wanting who believe, on the strength of their telescopic observations, that some low forms of vegetable life may be present there. But the moon is ours, and her life, if any, would be only a detached portion of terrestrial life; and, further, the moon has no atmosphere nor water other than may possibly remain in very small quantity in her deepest scars, or possibly—as regards water—on her hidden side. Any possible life that might exist upon the moon would thus be not only terrestrial historically, but humble now.



ARE NEW CANALS BEING MADE ON MARS TO-DAY? TWO VIEWS WITHIN A FEW WEEKS

The marks emphasised on the right-hand picture of Mars were never seen before October, 1910, and are assumed to be new canals.

Very different is the case of Mars, the ruddy planet named after the god of bloodshed, for life thereon would be, so to say, indigenous and original; and certain faithful, honourable, devoted, and expert observers report that they have direct evidence not only of life on Mars, but of provident, deliberate, constructive, and social life such as might well transcend, in all noble essentials, the life of man so far as that has hitherto attained on this younger planet.

Mars is a member of the sun's family, and the sun is only one of the innumerable stars. We must later discuss it adequately, but proportionately, in its place as a planet. Yet on account of its unique relation to our universal question we must deal with it specially here as a possible abode of life, and even of intelligence.

The Martian controversy, now more acute and interesting than it has ever been, began in 1877, a particularly favourable year for observation, the two planets being

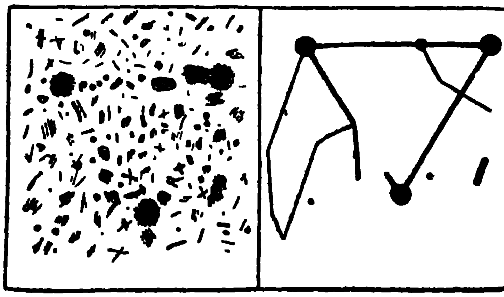
unusually near at "opposition"—when the earth is exactly between the sun and Mars, and these thus oppose each other—and the controversy began with the discovery of new features upon a surface till then supposed to consist of smooth oceans and continents. The discoverer was the Italian Schiaparelli—lately dead, after having lived long enough to see photographs confirming his visual observation of thirty years before; and if it should be one day proved that Mars is inhabited, it will seem appropriate that an Italian observer of the nineteenth century should have taken the first step in proving the full case of the Italian philosopher of the sixteenth century.

Schiaparelli found markings upon the face of Mars, which he presumed to be channels for water, and which he accordingly called by the Italian word for channels—which is *canale*. This we too, schoolboywise, have translated into English as "canals," with the serious objection that we have thereby introduced what Jeremy Bentham would have called a "question-begging epithet," which goes a long way to assume what has yet to be proved. "Canals" suggests intelligent construction to Anglo-Saxon ears.

THE GREAT HEIGHTS OF THE EARTH IN ARIZONA FROM WHICH THE PROBLEM OF LIFE ON MARS IS BEING INVESTIGATED BY THE NEPHEW OF JAMES RUSSELL LOWELL

"Channels" is a neutral term which does, indeed, assume more than Schiaparelli, or anyone else, has yet proved, but certainly does not suggest necessary engineers. We must beware, therefore, of our illiterate translation of Schiaparelli's Italian. And we must also beware of assuming without evidence that even his term, accurately translated, is unchallengeable. His "channels" might, indeed, convey neither water nor anything else, as is the business of a channel; for some have argued, not without force, but with illustrations drawn from the earth, the moon, and Venus, that these alleged channels are not channels at all, but cracks, violently formed in the crust of the planet as it cooled.

But, indeed, the controversy concerns itself with a much earlier question than that of canals versus natural channels, or channels versus cracks. The question at issue has long been, and according to some still is, appearance versus reality, a host of critics having long denied that these alleged markings have any real or objective existence at all, or are more than the creation of the enthusiast's brain, or overstrained or weary eyes; or the quality of the mind whereby a row of spots or dots may be constructed into a line; or even no more than the shadow of the blood-vessels within the eye, cast upon the retina and so seen by the brain, and misinterpreted as markings upon a planet fifty millions of miles away!



IS PROFESSOR LOWELL DECEIVED?

This diagram bears out the contention of some critics that what Professor Lowell thinks canals are illusions. Hold this 20 feet away, and the marks on the left look like the lines on the right.

The champion of the canals, even in the full meaning of the term, and of all that that would imply, has long been, and still is, Prof. Percival Lowell (a nephew of James Russell Lowell), who is director of the observatory at Flagstaff, Arizona, specially built by himself now many years ago at his own expense, in the most suitable atmosphere and climate that could be found, for the express purpose of studying Mars, and finding the truth as to this almost overwhelming question.

Lowell is in no danger of being burnt, but his scientific reputation, if not his body, is certainly at stake in this matter. He has already convinced himself, and a number of those who have had his admittedly unparalleled advantages in the study of Mars, as to the nature of the facts; and recent observations made at Flagstaff will have very greatly strengthened his case, if they be verified.

As he sees it, Mars is a planet which has nourished a great civilisation, now in its death-grip with thirst, mortal enemy of all life. Its small size has prevented it from retaining the water-vapour in its atmosphere as long as a larger planet, with a stronger force of gravity, might hope to do. The inhabitants, united in the face of common danger, have constructed a mighty system of canals to convey their scanty supply of water from the polar caps of snow for a week or two each springtime, to renew such life as it will suffice for. Beside these canals, and at the oases where they intersect, vegetation grows, changing from green to brown with the changing year, and contrasting with the ruddy desert glow of the remainder of the planet's surface. Once every Martian year each polar cap, in its turn, acknowledges the spring by melting and shrinking in area; and the canals become more prominent, owing to the increase of the vegetation that lines their shores. Thus the Martians, whose existence the character of these canals demonstrates, afford the inhabitants of earth a lesson, a warning, and an inspiration—a lesson in what can be achieved when intelligence unites for the common welfare instead of being divided against itself, a warning of what may some day be the fate of the earth, and an inspiration, of courage undaunted, of life that will fight to the end and never say die.

More especially must we lay stress upon three points: First, the photographs of the canals taken at Flagstaff, which do appear—though not yet with absolute finality—to dispose of the critics who deny the reality of any linear makings on Mars at all; second, the still more recent demonstration, apparently quite satisfactory, of oxygen in the thin atmosphere of the planet; and, third, the apparently complete demonstration of the presence of water-vapour in that atmosphere. These three achievements are very recent, and require further confirmation, but they are of the highest importance, and

represent success on the part of Lowell and his assistants in the very points at which they have longest laboured. The photography of the canals, if assured, absolutely establishes the existence of the markings, and completely changes the plane of the controversy; the demonstration of oxygen, which is necessary for all earthly life, deprives the opposing school of an argument so formidable that no man of science could get past it; and the demonstration of water-vapour has satisfied practically all impartial persons that the polar caps of Mars, whose existence is not questioned, are indeed made of snow, and not of solid carbonic acid, as some critics have suggested.

This brings us to the heart of the present argument, for all our speculations revolve round the presence of water on Mars. If the polar caps be snow, as there was never any reasonable reason to question, and as their behaviour—increasing and decreasing in winter and spring—would indicate, and if there be water-vapour, confirming these appearances, in the Martian atmosphere, we have to admit that Martian life, if such there be, must be in imminent danger of dying of thirst, so scanty at the best is the water supply. The "oceans" are waterless

MAPS OF TWO WORLDS—THE EARTH AND MARS COMPARED

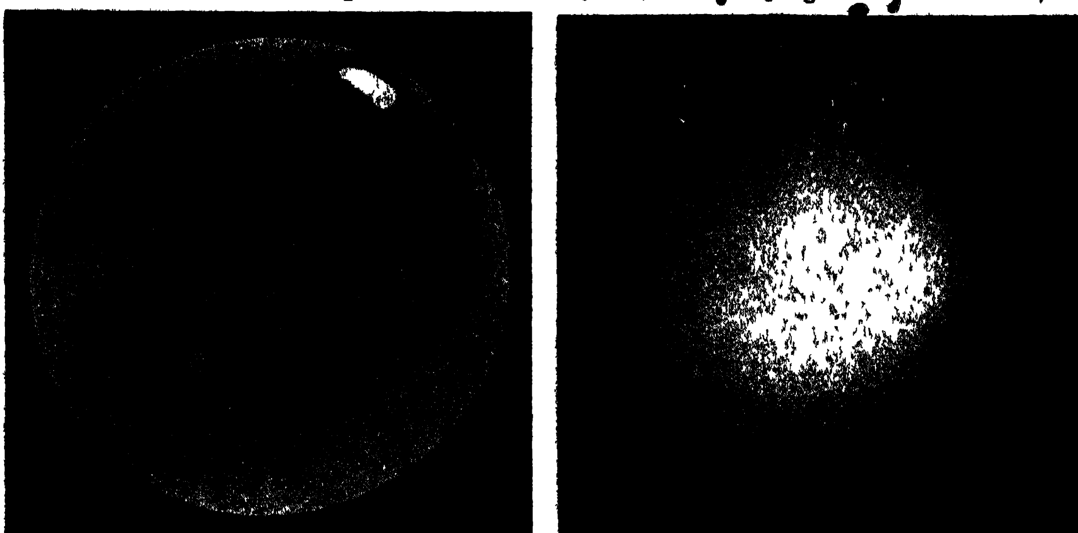
Long before men found the Poles of our own earth we could fix our telescopes on the Poles of Mars, which the top map shows to be marked out into areas clearly defined and named. The map of the earth has been drawn upside down to correspond with the way in which Mars appears to spectators on the earth, and the waters have been drawn dark to correspond with the dark areas of Mars, which are supposed, by Professor Lowell, to indicate the presence of water and vegetation, and therefore the possibility of intelligent life.

now, whatever they may once have been; and the canals traverse them, as they do the continents. The ruddy tint of the planet is probably due to its surface consisting almost wholly of desert sand; earthly deserts, seen from a height, glow similarly.

Mars, in a word, appears to be drying up, as may possibly be the case with our own earth. Mars is older, and the process has gone farther; nearly all the water has been lost from the atmosphere or by sinking through the crust. But an older planet might be expected to have developed higher forms of life, or higher forms of civilisation, than the earth yet displays. It might be expected that wars would have ceased and frontiers disappeared in the presence of a common danger, and under these conditions a highly developed race might imaginably make a common effort, encompassing the whole planet, for the maintenance of its life to the last possible moment.

As this line of thought would suggest, Professor Lowell and many other students of the planet believe that the canals *are* canals, made by intelligent beings, and demonstrating their existence to earthly eyes. Lowell believes that he has watched the complete sequence of the Martian seasons. Whatever hemisphere be studied, in spring the polar cap begins to melt, and the issuing canals become more marked as the water flows into them and vivifies the vegetation which lines their banks, and which, indeed, rather than the canals themselves, we really see. At many points where two or more canals intersect, there are what Lowell calls oases, areas of vegetation, showing seasonal change, and large in proportion to the richness of their water supply. These places are what Professor Lowell would call perhaps the "vital places" of Mars, corresponding with our great centres of population.

Such canals, geometrically straight as they are on both hemispheres of the planet, and planned on a planetary scale—some of them thousands of miles long—would require an intelligent population which formed one community and looked upon and treated its planet as a whole. Even so, the task would be a formidable one, especially as we must suppose the population to be scanty, water being so scarce, though, indeed, the work might have been done, for the future of the race, in times less parched and more populous. In any case, the work, judged by earthly standards, must have been colossal, stupendous beyond anything ever dreamed of by man: according to Professor Lowell's own estimate the canals must have a total length of 700,000 or 800,000 miles—about thirty times the distance round our earth! Here, however, Lowell is ready with an observation, undoubtedly just, which shows that earthly standards do not obtain everywhere. No astronomer doubts for one second that the law of gravitation obtains on Mars as on the earth. But, just because it does so, the weight of things must be far less on Mars, as the planet is much smaller than the earth, and accordingly pulls with much less force upon matter at its surface.



A SNOWSTORM ON MARS AND THE EXTRAORDINARY SPREADING OUT OF SNOW FROM THE SOUTH POLE

The first of these photographs shows what Professor Lowell calls the beginning of a huge fall of snow on Mars; the second shows the snow-cap of the South Pole of Mars at its greatest extent. The great spreading of the snow covers, it will be seen, about a quarter of the planet. Professor Lowell supposes that the melting of this snow fills the canals upon which Mars depends for the prolongation of its life.

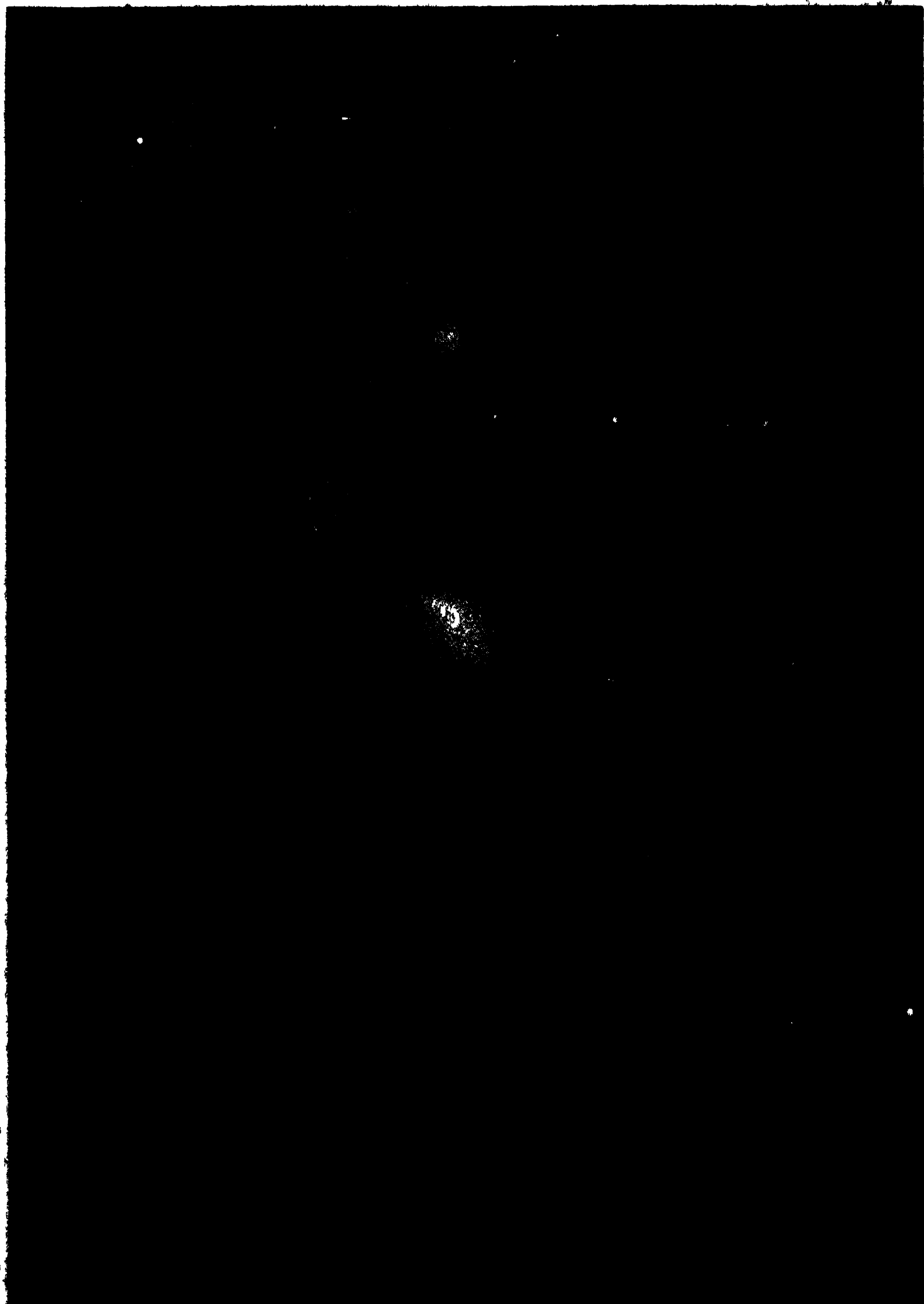
Canals, therefore, which it would be a herculean labour to dig on earth, would be almost an easy task on Mars. "A ditch seven times the length of one on earth could be dug as easily on Mars." Making the dirt fly is child's play if only a little planet is pulling it down, and to dig a Panama Canal on Mars would be vastly easier than world, whose few last inhabitants are fighting, inch by inch, a losing battle against the spectre of thirst, which will finally achieve their extinction. Confined to a few lines, and spots, their very oceans having been deserted by their water and become deserts, these brave, united, resourceful, provident folk have constructed

THE WATCHMAN OF MARS AND HIS GREAT TELESCOPE ON THE HEIGHTS OF ARIZONA
Professor Lowell in the observatory he himself built at Flagstaff, where he has for over twenty years studied the movements of Mars

on earth, just as it would be vastly more difficult on gigantic Jupiter.

Many other considerations are involved, many more facts and confirmations are required. But whatever the ultimate verdict may be, science and imagination alike must ever be indebted to this coherent, logical, and affecting account of the drama which Lowell has witnessed or imagined upon our neighbour's surface—the drama of a a system of canals which lead the water from their polar caps to fertilise what it may of their temperate zones. When at last the water fails they will disappear, as many an earthly civilisation has disappeared, leaving these monuments of their greatness for the admiration at some far day—nay, for the imitation—of another and alien but neighbourly race, born of a younger mother whom we call the Earth.

WORLDS EVOLVING BEFORE OUR EYES



A WONDERFUL PHOTOGRAPH OF A NEBULA FROM WHICH NEW WORLDS MAY EMERGE

The mighty nebula of Andromeda, filling space for millions of miles, is a huge area of incandescence such as the earth and our solar system are supposed to have been. From some such fiery cloud our earth must have evolved, and from this cloud itself are now evolving new worlds before our eyes.

THE BIRTH OF THE EARTH

The Amazing Beginning of the Flying Ball on which we Ride Thousands of Millions of Miles

WHERE DID THE WORLD COME FROM?

COMPARED with the colossal world he inherits and inhabits, man is a pigmy. Three acres and a cow suffice to feed him; a few sods of turf suffice for his last resting-place.

How, then, could primitive man obtain any adequate notion of the shape and size and character of the planet which whirled him round the sun? He had no telescopes, no motor-cars, no Mauretanias, no aeroplanes; how could he, with eyes, and legs, and chariots, and coracles, get any idea of the nature of his terrestrial home? Knowing the world but fragmentarily, he fancied it flat like a pancake, and thought it stood still in the centre of crystal spheres which carried the moon and the planets round it.

Of such small conceptions of the world the literature of primitive peoples is full. The Hindus imagined the earth borne by a huge elephant standing on a gigantic tortoise swimming in a sea of milk; and even the wise Greeks ended it at the Pillars of Hercules, and surrounded it with a misty world of dreams, where golden apples grew in enchanted gardens, and lotus-eaters were "propt on beds of amaranth and moly."

It was inevitable, perhaps. Even now, in these days of enlightenment, we do not know so much about our planet as we might. The writer asked an educated man the other day how many miles the circumference of the earth measured, and he guessed about fifteen thousand, though every schoolboy ought to know that it is almost ten thousand more. Nor is it at all an uncommon thing to find people, supposed to be educated, who believe that the moon shines by its own light.

The astonishing thing is, not that primitive man should have had wrong theories, but that primitive man should have had the courage to theorise at all on such tremendous and bewildering themes.

But from all time little men with big hearts and minds *did* tackle such problems; and though their first attempts were bound to be futile, yet by degrees, in one way and another, they found out a great deal about the big planet on which they lived.

Nor were the big hearts and minds content to know the world merely as it is—they sought to see it as it was, in its babyhood; they sought to discover when and whence it came, and how it grew. Poets endeavoured to imagine their way back to the first beginnings, scientists and philosophers endeavoured to reason their way back, and by the exercise of both imagination and reason men have learned something of what must have happened in the dark backward and abysm of Time.

It is quite certain that the earth has not always been in its present condition. Day by day, year by year, we can watch the surface of the world changing. We can watch mountains tottering, glaciers dwindling, islands upheaving; we can watch ice and snow, and tornado and sea, and earthquake and volcano at their destructive and reconstructive work; and geology teaches us that such changes have been occurring for ages that we cannot count. We find the remains of ferny tropical forests amid the Arctic and Antarctic ice; we find the signature of glaciers on the rocks of pastoral lands; we find sea-shells on mountain-tops and cities under the ocean. Moreover, we know that the earth is slowly cooling down, and that once it must have been molten.

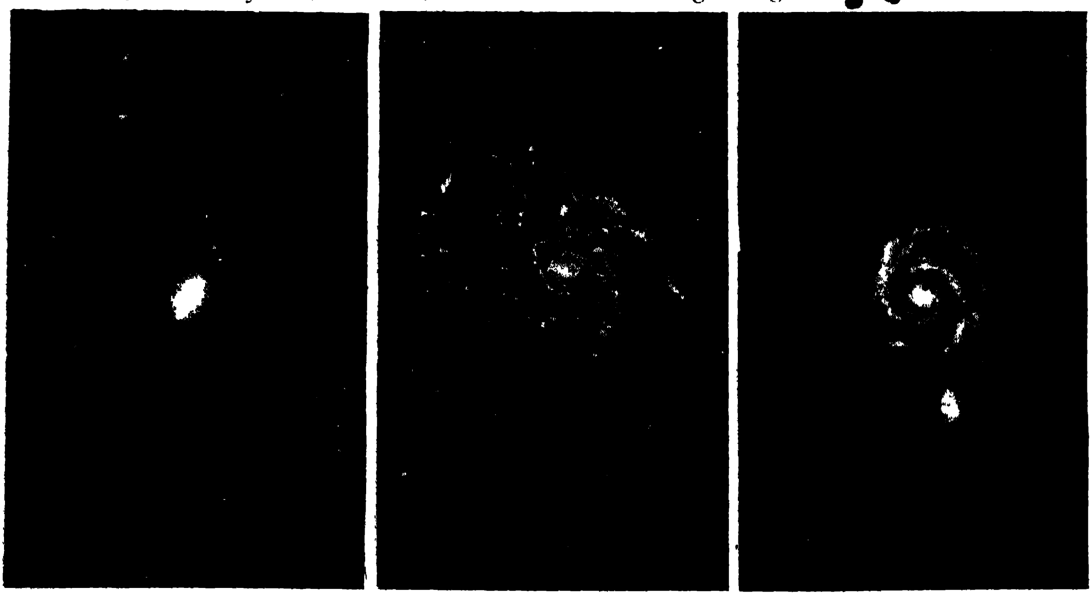
Where, then, did the earth come from, and in what shape did it first appear?

About a hundred and fifty years ago, the superbly audacious nebular theory blossomed in a few great minds, and round this theory cluster all the theories of the making and shaping of the earth. The

idea was advanced in various forms by various thinkers, and is fully described in another part of this work, but here we may give an idea of its broad features as Laplace conceived them.

According to this view of Laplace, all the members of the solar system were originally blended in a whirling mist of incandescent gases. At first the mist of fire extended beyond the outermost planet of our system—that is to say, beyond Neptune. It must, therefore, have been nearly a million times the size of our sun. The mist cooled and contracted, and as it contracted, it spun faster, according to a well-known law. Now, if we twirl a mop faster and faster, the water begins to fly off, and so, as the bulged at its equator and flattened at its poles, and when it was made to rotate more rapidly it threw off successive rings of oil which broke and formed balls that rotated on their own axes, and revolved round the central ball of oil.

According to this audacious and magnificent notion of Laplace, the earth, the sun, and all the planets were first incorporate in one tremendous cloud of fire, and the earth was once a belt round the waist of the whirling sun. The idea is in accordance with many of the facts, and certainly appeals to our imagination. We find Saturn at present wearing just such belts as Laplace described, and we find space filled with glowing, whirling nebulæ. Still,



WHAT IS HAPPENING IN THE HEAVENS NOW—PHOTOGRAPHS OF WHIRLING SPIRAL NEBULÆ

These photographs of sights that may be seen to-day through a telescope illustrate the way in which it is supposed the earth and the solar system were evolved; and they show, too, especially the centre picture, the throwing off from a central body of huge masses which may be vastly bigger than our earth, and are properly described as new members of the company of worlds.

rotating fire-mist spun faster, it flung off a belt of substance much like Saturn's belt. The belt spun for a time, but soon broke, and collected into a big rotating ball—the planet Neptune. As the nebula still contracted, and still spun ever faster and faster, other rings were formed, conglomerating into planets, and one of these was the earth. The earth, of course, continued its spinning, its cooling and contracting, and one day as it contracted it threw off what is now the moon.

A Belgian scientist invented a very ingenious and striking way of illustrating this nebular suggestion. He floated a ball of oil in a mixture of water and spirits of wine, and contrived to make the oil revolve. As the ball of oil revolved, it modern scientists have found that the theory is not entirely satisfactory, and many modifications and amendments have been proposed.

The most famous of modern theories is the so-called "meteoric theory," which supposes the planets to have been built up from fragments of meteors. Between the planets of our solar system are swarms of stones and broken meteors careering wildly in all directions. When the larger fragments enter our atmosphere, friction with the air renders them incandescent, and if they are large enough we see them as what we call "shooting stars." It has been calculated by Professor Newton that about twenty million meteorites, each large enough to be seen as a shooting star, enter our atmosphere

every twenty-four hours, and the sun is probably pelted with them. Comets, too, are probably swarms of stones.

This theory supposes that nebulæ are not incandescent gases, but swarms of such stones banging about in an atmosphere of hydrogen. The stones dash hither and thither, colliding and clashing against each other. Some are converted into gas, some into molten metal, by the heat of the collision, and gradually they come together in larger stony masses, which attract other stones by gravitation

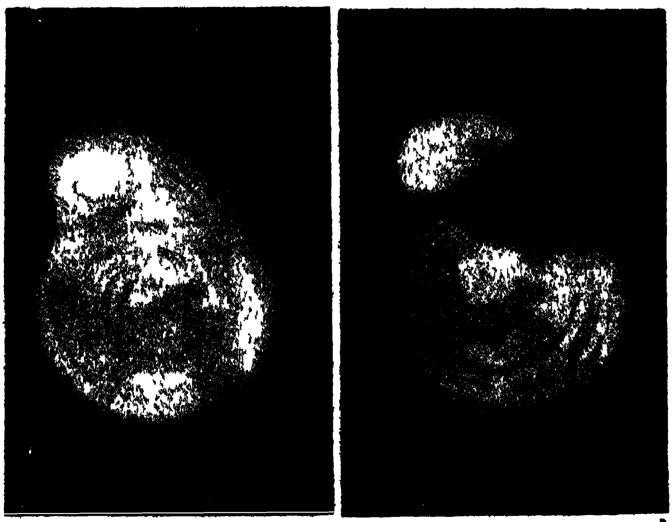
The exact way in which the planets are formed and set in their courses has not yet been worked out. Some hold that the stones dart about in all directions; others believe that they revolve in definite orbits round a central mass, and collide only where their orbits intersect. In any case, the ultimate result is a number of molten massive bodies.

Whether we choose to believe that the earth was formed from a cooling fire-mist, or from a hailstorm of stones, our imagination must be kindled by the sublime audacity of the conception. Equally wonderful is the picture of the earth emerging from a fiery cloud, or the picture of the earth battered and bombarded into existence by volleys of red-hot stones.

One more suggestion may be mentioned before we leave the subject. A few years ago Professor J. H. Jeans proved mathematically that a spherical nebula slowly revolving in a hot state must assume a pear-shape as it contracts, since it will cool more quickly on its surface, and must revolve more rapidly as it shrinks. Eventually there would be a tendency for the pear-point to fly off, especially if attracted by passing bodies; and so the consecutive formation of the planets might be explained, particularly the birth of the moon.

Earth bore the moon at least fifty-six million years ago; and it is very likely that at that time the earth was a pear-shaped mass of molten matter, whirling round the sun, and that the pull of the sun wrenched off the point of the pear, making a huge hole about twenty-seven miles deep, which has since become the bed of the Pacific Ocean. There is an opportunity for the imagination—the blue Pacific Ocean singing and surging in a scar in the earth's side, whence was torn the moon, and the moon tugging at the sea and giving it its rhythmic tides! Think of the hot steam condensing and boiling and bubbling in a terrific chasm twenty-seven miles deep, and how now

> The gentle moon, that nothing doth but shine,
> Pulls all the labouring surges of the world.



DOES THE PACIFIC OCEAN ROLL IN THE BED OF THE MOON?

One of the theories of the making of the earth, not widely accepted perhaps, is that when the earth was pear-shaped, centrifugal force wrenched off the point of the pear as it whirled round and round, making a huge hole about 27 miles deep, in which the Pacific Ocean now rolls.

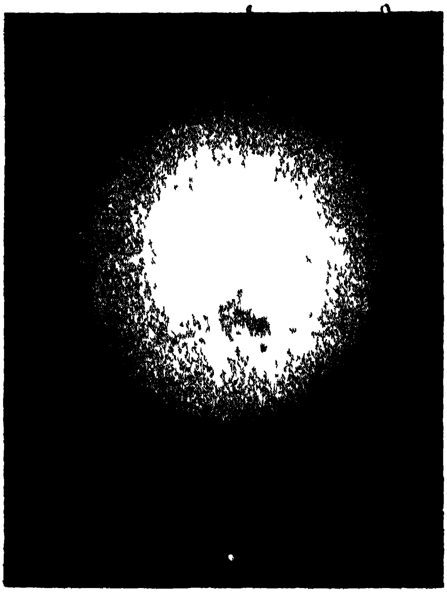
When the moon was wrenched off in this way, the earth was spinning at a tremendous rate, so fast that night and day succeeded each other every few hours, and the earth imparted such velocity and momentum to the moon that the moon rushed headlong through the cloudy heavens, rising and setting perhaps six times a day. A magnificent sight the moon must then have been, for it was only about ten thousand miles away; its enormous volcanoes, in full fierce eruption, must have been quite visible from the earth. That is to say, men might have seen fires burning on the moon. Then, too, it revolved on its axis, and showed to the earth its other mysterious side, "unguessed of mortals."

The tempests and tides must have been prodigious then, owing to the rapidity of the earth's rotation at that time and the nearness of the moon, and Sir Robert Ball has calculated that in early geological times the tides were over six hundred feet high, or higher than the huge chalk cliffs rising from the sea at Beachy Head.

Now the moon is 238,000 miles away; its volcanoes are extinct; it has forgotten how to spin; it moves with leisured pace;

and its tidal action is moderate. But we must look on it with respect and awe when we remember the story of its birth, and the fiery volcanic energy of its youth.

When the earth cooled down to a temperature of about 1,200 degrees (centigrade) it acquired a solid crust, and when the crust fell to a temperature of 370 degrees it began to condense steam out of its atmosphere. Wild, fierce days these must have been—days of molten metal in red hot cauldrons, of lightning and thunder, of earthquakes and volcanoes. Réclus gives a vivid picture of these first days of the earth: "When the temperature was lowered sufficiently to enable them to pass from a gaseous to a liquid state, metals and other substances would fall down in a fiery rain on the terrestrial lava. Next the steam, confined entirely to the higher regions of the gaseous mass, would be condensed into an immense layer of clouds, incessantly furrowed by lightning. Drops of water, the beginning of the atmospheric ocean, would begin to fall down towards the ground, but only to volatilise on their way and again ascend. Finally, these little drops reached the surface of the terrestrial mass, the temperature of the water much exceeding 100 degrees, owing to the enormous pressure exercised by the heavy air of these ages; and the first pool, the rudiment of a great sea, was collected in some great fissure of the lava. This pool was constantly increased by fresh falls of water, and ultimately surrounded nearly the whole of the terrestrial crust with a liquid covering; but at the same time it brought with it fresh elements for the constitution of future continents. The numerous substances which the water held in solution formed various combinations with the metals and solids of its bed; the currents and tempests which agitated it destroyed its shores only to form new ones; the sediment at the bottom of the water began the series of rock and strata which follow one another above the crust."



HOW THE EARTH SHRANK DOWN

The earth must have been many thousands of times its present size before it cooled down enough to be the home of life. This picture shows its probable appearance as a globe of fiery gas; the small dot below represents the earth as we know it, now that it has shrunk within itself.

Such, then, is the history of the fiery, turbulent past of the earth. What do we know about its more prosaic present?

Astronomically and socially speaking, the earth is a member of the solar system. Spinning on its own polar axis as it goes, it journeys round the sun along with Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune, and it is placed quite appropriately between Venus and Mars. It is almost round, but not quite, for it flattens out a little at the poles, and bulges a little at its equator. Its polar diameter is 7,899 miles, and its equatorial diameter about twenty-seven miles more. Its greatest circumference is nearly 25,000 miles. Its general substance is very dense, about twice as dense as granite and about five times as dense as water, contrasting in this respect with Saturn and Neptune, which are as light as cork.

Compared with other heavenly bodies, the earth is not large. It is larger than Mercury and Mars and Venus, but it is only a pea to a pumpkin compared with Jupiter, and only a midge to a mammoth compared with the sun.

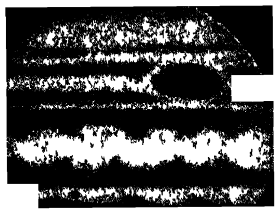
Nor is the earth's pace anything exceptional. In 365 days it completes an orbit of over 580,000,000 miles, so that it averages 18 miles a second, which is to say that it flashes through space about fifty times as fast as a rifle-bullet, and about a thousand times as fast as an express train. Not a bad pace, it may be said, but Venus and Mercury both go faster, and Arcturus goes nearly two hundred miles a second.

Not its size nor its speed, but its burden, is the boast of the earth. Whether it be the only planet that is the chariot of living things we do not know, but certainly it is the only planet that bears roses and trees and cabbages, beasts and birds and men. It is true that regular lines that are thought by some to be canals have been discerned on Mars; and both astronomers and novelists have been fain to imagine Martians; but, however Mars be—whether there be life on her or not—it is

certain that the life we live cannot be there, and that earth alone mothers men.

Round the sun speeds the earth; but the sun itself is not standing still; with all its retinue of planets it is rushing at a rate of ten miles a second towards the constellation of Lyra. Every year it is about three million miles nearer; and who knows for how many years it has been rushing towards its goal? Perhaps in a million years it will arrive there. But meantime our little solar system is isolated in space like a rock in the centre of the Atlantic Ocean.

Such, then, are the astronomical characters—such, then, is the rapid, rushing everyday life—of the earth. Why the earth spins and revolves, why all the planets spin and revolve, we do not know, further than that in their orbital revolutions they obey the same laws, and fall at the same rate, with the same momentum, as a falling apple. The moon *falls* round the earth, the earth *falls* round the sun, an apple falls to the ground. But though we do not understand the force of gravity that causes the particular motions—that makes moons and apples fall, and pendulums swing, and bullets describe the curves called parabolas—we do know that it is this force that holds the universe together; we know that if it were stronger the earth would fall into the sun; we know that if it were weaker the earth would fly off at a tangent like a stone from a sling; and we know, too, that to the earth's inhabitants the earth's tremendous motions have momentous consequences. It is the rotation of the earth on its axis that gives us day and night, and trade winds, and all that these mean; it is the revolution of the earth round the sun that gives us our seasons, and all that they imply. Let us look at the motions of the earth a little more in detail, considering what they mean.



A PICTURE OF A MOLTEN WORLD

One of earth's distant companions in her journey round the sun, Jupiter, is now in a molten state, as was the earth, which must have looked like this in the days before it formed its solid crust.

First, let us look at the earth's rotation on its own axis. The axis round which the earth revolves is a line passing between its two poles. Round this axis it rotates eastward, at such a pace that it turns completely round in twenty-four hours. This means that any point on the earth's surface at the equator rotates eastwards at the rate of 507 yards a second. But the axis of rotation of the earth is not perpendicular to the plane of its revolution round the sun; it is tilted in a certain direction relative to space. The result of this is that each pole in turn points towards the sun, and then gradually points away from it again—as may be illustrated by moving a leaning pen round an ink-bottle, and considering the nib the South Pole and the other end the North Pole. The result of this movement is that at any point in the earth's revolution the Northern or Southern Hemisphere will have more sunlight at a particular time according to the direction of the tilt of its pole relatively to the sun. When the North Pole points most towards the sun, the northern polar regions will have perpetual daylight and a midnight sun, and the Northern Hemisphere will enjoy its summer; while the South Pole and the Southern Hemisphere, leaning away from the sun, will be enduring their winter, with shorter daylight or without any daylight at all.

RINGS THAT GO ROUND A WORLD

Saturn, one of Earth's neighbours, pursues her journey through space inside mysterious rings that are probably made up of meteorites. Though several times as big as the earth, the planet is made of matter so light that Saturn would float in water.

As each pole in turn gradually approaches and gradually recedes from the sun, there must be points in the orbit of the earth where both are an equal distance from the sun. At these points night and day will be equal to each other in both the Northern and Southern Hemispheres, and so we get

the "equal nights," which we call the spring and autumn equinoxes.

If there were no tilting of the axis of rotation of the earth, if it spun "straight up and down," so to say, both poles and both hemispheres would always be equally exposed to the sun, and there would be no seasons, and day and night would be equal all over the world—twelve hours night, and twelve hours day.

Our seasons, then, and the varying proportions of day and night, and the necessary consequences of these things, are due to the tilting of the earth's axis of rotation. The tilt of the earth's axis of rotation is not quite steady and constant; it sways a little and describes a conical movement, a little like a wobbly spinning-top, so that its poles make small circles and point in circular succession to different stars. It takes 21,000 years to sway round a circle. The swaying of the axis is due to the attraction of the sun and moon acting on a body not perfectly round, but bulging.

Besides this conical motion there is a direct oscillation to and fro of the earth's axis of rotation, so that at times the earth spins more erect than at other times. The result, of course, is to alter the proportionate length of day and night at all seasons over most of the globe. When the axis is most tilted the polar regions enjoy about 8½ days more sunshine.

Thus our earth spins and wobbles and nods on its journey through the heavens.

Now let us look at the second great motion of the earth—its revolution round the sun.

In its course round the sun the earth describes an ellipse, not a true circle, and the sun is placed at one of the focus-points of the ellipse—that is to say, not at its exact centre. Accordingly the earth in its circuit approaches and recedes from the sun. At present at its nearest point it is 91,250,000 miles from the sun, and at its farthest point it is 94,500,000 miles away.

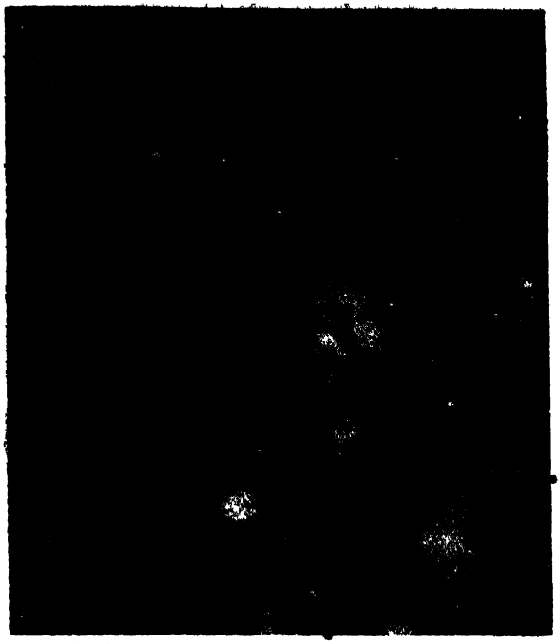
It is necessary to say *at present*, because the ellipse described by the earth is liable to be altered by the attraction of Venus and Jupiter, and at intervals of two or three hundred thousand years great eccentricities take place, so that the difference between the nearest and farthest points may become as much as 14,000,000 miles.

Summer and winter do not depend on the earth's distance from the sun, but on the tilting of the earth's axis. If the North Pole lean away from the sun, it will be winter in the Northern Hemisphere, whether the sun be near or far; and if it lean towards the sun, it will be summer in the Northern Hemisphere, whether the sun be near or far. At present the North Pole is tilted towards the sun when the earth is farthest away, and so we in the Northern Hemisphere have summer when we are farthest from the sun; and the opposite relationship obtains in the Southern Hemisphere. But we must consider this question when we come to speak of climate; the main facts to be noted now are that the earth moves in a variable ellipse, and is tilted on its axis to a varying degree.

Such, then, is the earth as we now know it—an oblate spheroid of great density spinning rapidly on a tilted axis as it rushes at the rate of eighteen miles a second round the sun. Such, then, is the earth, wobbling a little as it spins, and becoming rather eccentric now and again when attracted by Venus and Jupiter.

We have spoken of the motions of the earth in their relations to light and darkness, summer and winter, but it is too often forgotten that these motions may have vital significances—must, indeed, have vital significances—of which we know nothing. The terrific career of the planets through space must have infinite consequences. Think how the earth spins on its axis and flashes eighteen miles a second through the ether! It is certain that that motion must affect light, electricity, gravitation, and all forces that we know on the surface of the earth. Suppose it were possible for the earth to stand still, can anyone believe that light and heat, and all the waves of ether

THE WORLD GOING ROUND, SHOWING HOW ONE PLACE TRAVELS 25,000 MILES IN A DAY AND NIGHT



A NEBULA THAT NO MAN HAS SEEN

A NEBULA IMMERSED IN STREAMS OF STARS

The photographs illustrating this article were taken through the famous telescope at Yerkes Observatory, Chicago, by Mr. G. W Ritchey, except that on the left of this page. This photograph, taken by Mr. E. E. Barnard, can only be studied photographically, being too faint to be seen even through the telescope.

proceeding from the sun, would not have consequences quite different? The motions of the earth, then, must be considered not only as the causes of night and day, summer and winter, and trade winds, but as also a factor in all the great world-forces which have cosmic relations.

Man, as we said at the beginning, is a pigmy compared with the world he inhabits; but let us never forget that, big though the world be compared with the creatures it carries, it is yet but a speck compared with the colossal masses with which all space is strewn. The earth is less than one-millionth part of the size of the sun; yet the smallest nebulæ we know are larger than the sun, and some of the larger nebulæ confound imagination. "The earth," writes Sir Robert Ball, "sweeps around the sun in a mighty path, whose diameter is not less than 185,400,000 miles. Let us imagine a sphere so mighty that the circle would form just such a girdle round its equator, and let this gigantic globe be the measure wherewith to compare the bulk of the vast nebula of Orion. It can be demonstrated that a million of these mighty globes rolled into one would not equal the great nebula in bulk, though how much greater than this the nebula may really be we have no means of ascertaining." Yet the nebula of Orion is only a shred compared with the Milky Way!

And space is thronged with enormous masses of which earth is *one*, one of a host unthinkable—millions and millions of shining suns, and millions and millions and millions of burnt-out suns; for luminous suns are merely the glow-worms and fireflies of space, and comparatively quite as rare.

We have merely glanced here at the general characters of the earth and its relation to the cosmos, but enough has been said to show the grandeur of the starry stage on which we mortals play our little parts. It rests upon us not merely to know, but to realise, these great facts—to realise that the earth is not the earth of our visual horizons, but a great globe whirling through space—a great globe with a fiery past, one in the brotherhood of innumerable suns and stars that people space. If we can realise this, life becomes a greater and diviner thing. Surely a nebula is large enough to burn up all the petty cares and fears of life.

Well may we think of the magnificent lines of the ancient poet—

"Where wast thou when I laid the foundations of the earth? Declare, if thou hast understanding. Who hath laid the measures thereof, if thou knowest? or who hath stretched the line upon it? Whereupon are the foundations thereof fastened? or who laid the corner-stone thereof, when the morning stars sang together and all the sons of God shouted for joy?"

THE VOYAGE INTO AN UNKNOWN LAND, WHICH ALL MUST MAKE ACROSS THE SEAS OF TIME

"WHERE LIES THE LAND TO WHICH THE SHIP WOULD GO? FAR, FAR AHEAD, IS ALL HER SEAMEN KNOW"

This beautiful painting of life's last journey, now in the possession of Captain Godfrey Webster, R.N., is by Mr. Byam Shaw, and is called "Whither?"

THE MYSTERY OF MYSTERIES

The Preparation of the Stage for the Great Play of Life in the Universal Theatre

HOW LIFE SWEPT ACROSS THE EARTH

FOR ages unimaginable the universal forces had been building a theatre, and setting the stage for the play of Life—a drama which will reach its appointed end, through and beyond us, the actors and spectators—when the idea is fulfilled of the Omnipotent Author, whose power and purpose are behind the timber of the stage, the line and pigment of the canvas, every atom and iota of the setting of the scenes. All the world's a stage, and all the living things the Author's players.

No image can do justice to the theme, but this of a drama has suggested itself again and again to great thinkers and poets since the dawn of recorded thought. And the more we study the being and becoming, the doing and the suffering of life, the more do we perceive that the whole creation groaneth and travaileth together, living and dying, eating and eaten, pursuing and pursued, begotten and begetting, loving and hating, in sea and soil and sky, not by chance, but to some destined end towards which they also serve who see it not at all. This, of which human dramatists and reformers are themselves the creatures, can scarcely be less "a play with a purpose" than any of theirs.

To this great vision of the world-drama we shall return at the close of our brief bird's-eye view of the action as we see it now, and as we can thence infer it in the acts which were already played before we came upon the scene. Meanwhile—failing a literal biograph which might recount for us the creative doings of the past—let us try to perceive, in the mind's eye, the main happenings of this incomparable pageant.

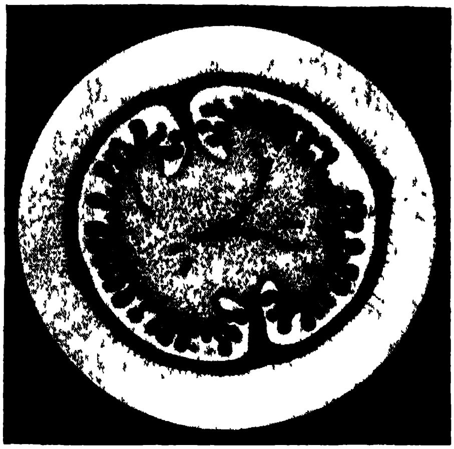
Briefly, they are these. Cosmos ever emerges from chaos, order and structure from disorder and incoherence; a fire-mist, a rounded world—and upon its still heaving and violent surface a little self-contained frame of life, a microcosm, or little cosmos; and, finally, the spectacle of ordered life in its highest form—the body of man, with its tremendous companion, Mind, incomparably and unchallengeably the highest thing we know. Fire-mist to earth is chaos to cosmos, earth to life is chaos to cosmos, life to mind—the billions and billions of cells that make up a man's body becoming the vehicle of his single self—is yet again the emergence of cosmos from relative or seeming chaos. Well may we speak of Creative Evolution, which thus ever brings forth order from disorder, the high and rare and intangible from the low and gross.

While we ponder on this great idea, which surpasses the mechanical, meaningless evolution of nineteenth century thought as that surpassed the "special creation" of its predecessors, let us beware of supposing that what appears to our eyes to be chaos is chaos indeed. The glowing, twirling nebula is only a chaos relatively to the solar system, the crust of the earth is a chaos only relatively to the plant in one of its crannies, the body of man is chaos only relatively to his Self. All that *is* was contained in all that *was*—nay, all that will be, as far beyond our imagining as Shakespeare's "Hamlet" is beyond an ape's, will have been contained in the seeming murk and muddle of the past. Order and law and growth and achievement are not really new; man's greatest deed of the next century is already, in a sense, achieved—the universe has been working thereto, "without haste and without rest," and without doubt or risk, through all the ages of the ages.

If we should continue to err in understanding this, we are without hope of ever finding the goal of truth. The living and the dying, the struggle and the mutual aid,

the hopes and fears, the changes and chances, the laws and the liberties of life, were better left unobserved and unconsidered if we are to suppose that they are of the nature of a fluke, a kind of accident or disease afflicting the earth's surface, and by no means an integral part of the universal scheme. So to suppose is to deny the first and last law of all science and all reasoning, which is that Causation is universal, and that all stages and all processes are equally necessary and natural, all alike the immediate and premeditated manifestations of the Power that moves through all things. However we conceive or imagine that Power, in its eyes all its work is equally good; and if at times it seems to our eyes to excel itself—as in the evolution of man—let us not have the folly to suppose that its commonplaces are inevitable and its masterpieces accidents.

Not so are any masterpieces made, human or divine; all alike are but special manifestations of the laws and the powers which operate everywhere. And just as we judge a man by his best as we reckon best, so, if we are wise, shall we estimate the poetic or creative Power which at one time makes the mouth of the hippopotamus and at another the mind of man, but which is yet the same infinite Power at all times, in all places, and in all its deeds.



CELLS OF LIFE
All life of whatever kind, animal or vegetable, is lived in cells, of which these two are types—from a potato.

It were doing poor honour to our subject if we did not preface it with such statements as these. But let us now proceed to survey the spectacle of life taking possession of the stage, or mansion, or locomotive—for it is all these—which, through millions of years, had slowly become ready for its task.

The conditions of the beginning must be studied in a succeeding chapter; here it is only necessary to be assured that, notwithstanding the fantastic hypotheses of past times, the life which has taken possession of the earth is itself the child of earth. That which was true in the beginning, is now, and ever shall be. Other forms of life may have been born, and may be born, on other planets. On that we can do little more than speculate as yet. But terrestrial life is born of Mother Earth. Of life in all its forms, from microbe up to man, earth is the womb and the tomb. If life should attempt to establish itself without reference to the conditions the earth imposes, it must fail. This is true of the tree in the wood, and of the man in the street. Failure to recognise it is the constant tendency of civilisation; the civilisation which does recognise that the laws of life are imposed by earth, and are the laws of all life, will be the first to endure and the last to survive.

When the time was ripe, life took possession. We say it is a child of earth; perhaps we should more accurately say that life, like the fabled beauty of the ancients, was born of the sea. Our present concern is no more than to realise that, some time after the surface of the earth cooled sufficiently for water to exist in liquid form, but certainly not before, life was born. The metaphor of birth is more than obviously appropriate to the coming of life; it suggests the truth upon which we have already insisted, that this was not the appearance of a new thing from nowhere, but the coming to birth of that which Earth had carried within her womb since she was earth at all.

Instantly, if we may judge at all by the consistent behaviour of all the forms of life that we now know, life took possession of its planet. With its original and inexhaustible genius, it created new forms to suit an almost infinite variety of terrestrial circumstances. To-day the earth literally teems with life wherever the "irreducible minimum" of conditions is complied with. So rapid and thorough is the penetration of new life whenever it obtains a new chance—as when the rabbit is introduced into Australia, or the microbe of plague into Manchuria, or some European weed into American streams—that we may reasonably suppose this teeming state of life to have been established with extreme speed after the first coming of life at all, and to have been the condition of our planet ever since.

The forms have been various indeed; the degree and what we may call the intensity of life may have varied, as when we compare

the ox and the tiger, or almost any plant with almost any animal; but the extensiveness of life is of old standing, and nothing can resist it if the conditions of its nourishment be complied with.

Life cannot grow in the waterless desert, nor in carbolic acid, nor in an atmosphere of nitrogen—except for some microbes which can get oxygen to breathe by breaking up compounds containing it; yet, given the conditions of any life at all, all the life possible will avail itself of them. To this proposition, which has been wholly true until almost our own times, there appears to be a unique and staggering exception, wholly without any parallel in the animal or the vegetable world, furnished by those human communities whose members do not multiply, even though food and room be available. Apart from this exception, which involves the destiny of mankind as nearly as anything that can be named, it is and always has been universally true that life irresistible must go everywhere; and indeed, having conquered the earth, begins to wonder, in the mind of its protagonist man, whether it may not conquer other worlds as well.

This exception seems a real one, but life is not mocked, even by man. If man, in his unparalleled fashion, does not choose to multiply as he might, then lower forms of life, animal or vegetable, will utilise the space and the opportunities which he refuses, as, for instance, in the case of two recent immigrants into Australia, the white man and the rabbit.

We here speak and think of life as one, despite the bewildering and staggering multiplicity and contrast of its forms—man himself, and the parasite that causes his hair to become thin, the grass growing under his feet, and the lark flying overhead. But all life is veritably one, the laws of any life are the laws of all life, and all living things are brothers and sisters, or cousins at the least. Job said that man is a worm, and modern science knows that he is historically descended from a worm-like form. If there were no microbes there would be no man, for the earth would be an uninhabitable charnel house without their ceaseless labours of putrefaction and fermentation, by which the earth is kept ever clean and sweet for new life. If there were no man, again, many recent forms of microbes, which can only live inside his body, would not exist. Thus, though the struggle for life between the man and the microbes may not appear fraternal, it is inevitably fratricidal; struggle though they may, they are mutually

THE BIRTHPLACE OF LIFE, WHICH MUST HAVE COME OUT OF THE SEA

Reproduced by permission from the painting by Mr. Joseph Farquharson, A.R.A., in the Walker Art Gallery, Liverpool.

dependent brothers. Again, "all flesh is grass" in the profound sense that, but for the grass and its chemistry, there would be no food for animals, and therefore no flesh—which is as true of human flesh as of bovine; of the meat-eater as of the vegetarian.

Living things may be animal or vegetable, large or small; they may flourish in the lowest and blackest depths of the ocean, miles below the surface, or upon the dizziest crag, like the eagle or mountain-ash, but they all consist of cells, they must all breathe or die, feed or die. Prussic acid, chloroform, alcohol, carbolic acid, in sufficient concentration, will kill a whale or a microbe or an oak or a man; and each of these will equally die if atoms of the element carbon, or of nitrogen, or of oxygen, or of phosphorus, or of hydrogen, be omitted from its diet.

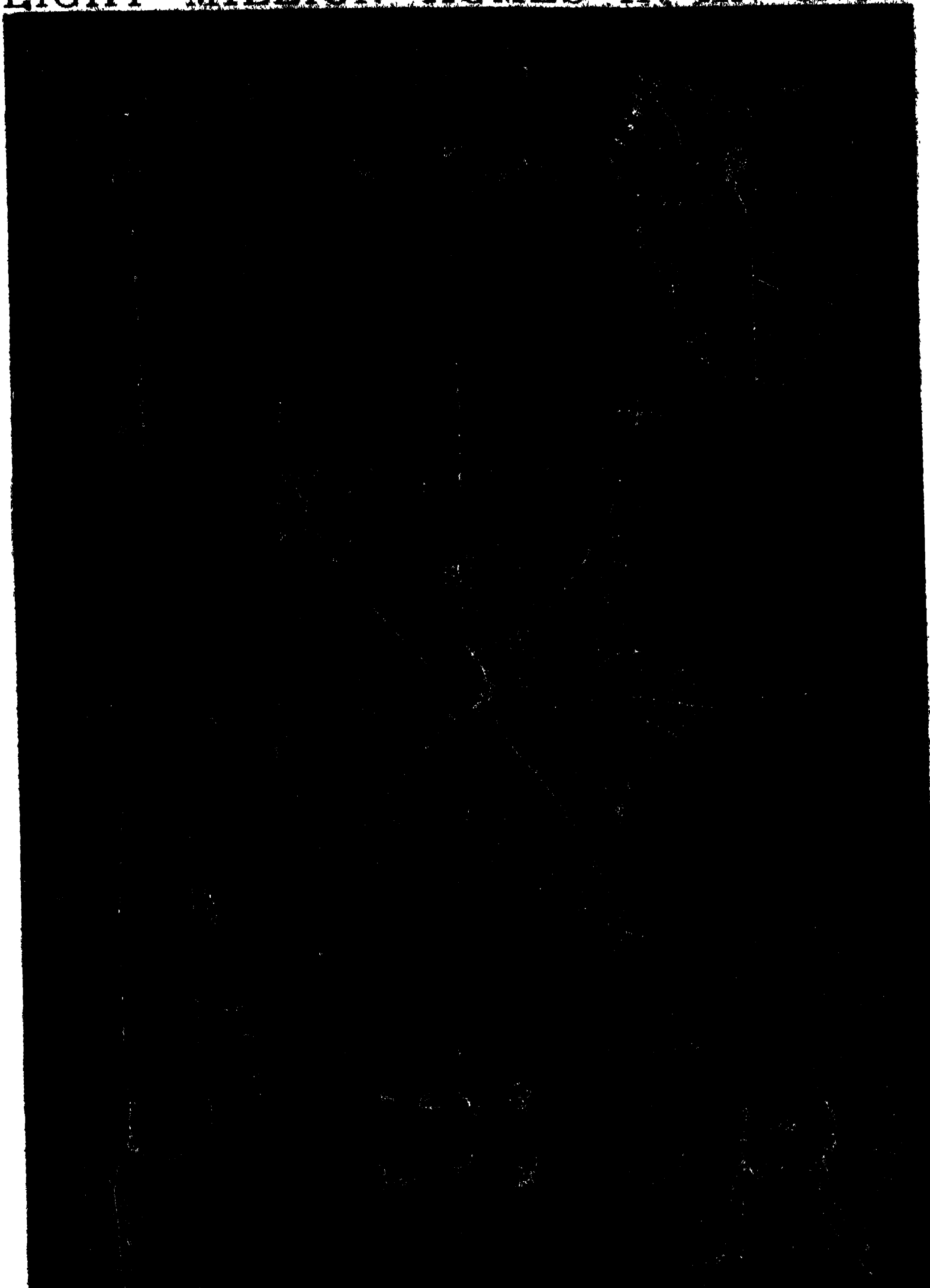
I write in a garden, and evidence of the variety and the unity of life is all around me—birds overhead, grass under the hides of oxen which I wear on my feet, countless varieties of vegetable microbes and minute animal forms of life are in the soil, or there would be no grass. I am eating the fruit of a tree, and the pips which I reject stand for the future perpetuation of life, which is the first and most constant desire of living nature, much more constant and profound, indeed, than the "law of self-preservation." A small human child plays upon the grass. The harsh, repeated cry of a blackbird in distress reminds me of its young, for which it fears, as I do for my little daughter, when she starts to eat an unripe apple, the child of the tree beside me. I look round, and see the expected cat, the cause of the blackbird's distress. The cat has its own needs, for self and for its young, and they conflict with the blackbird's, as mine do with the object of the orange tree, whose [illegible] I am destroying. I mark the marvellous quietness of the cat's approach, the breadth of the bony arches which carry the muscles whereby it bites so strongly and surely, as the blackbird well knows, and I perceive that life, imperious, inexhaustible, patient and impatient, frugal and lavish, protean and constant, is endeavouring to fulfil its inalienable purposes in all of us, from the soil under my feet to the brain whereby I am now earning my children's bread.

"LIFE COMES ASHORE"
From an original drawing by Sir Harry Johnston

Well may Bergson, the great new thinker, declare that there is a profound and significant contrast between the course of what we call inanimate matter, and the course of life. In the inorganic world the tendency is ever downwards, in a sense, towards the "dissipation of energy," as Kelvin called it, towards the lowest level, as water falls—unlike the blood of man, which surges upwards, brainwards, from the pulling earth—towards the line of least resistance. Life, on the contrary, notwithstanding its obedience to the universal laws, is ever pressing onwards and upwards. Not for it is the line of least resistance—it may use that line, and does, but not for its own purposes, which are those of *most* resistance. Atoms disintegrate, even the glories of radium depend upon its destruction and resolution into simpler, lower forms. But life creates, constructs, invents, fights, adapts, conquers, ascends, and is not satisfied.

This is what Bergson calls the *élan vital*, which we may most briefly translate as the "go" of life. There is nothing like it. It is marvellous in the sprouting seed; it is divine in the pioneer of thought; but, whether in the acorn or in a Newton or a St. Francis, it is a manifestation and unique characteristic of what we call life. We may be put hard to it to define the term, but there can be little doubt of what we speak, when it displays such deeds as these. No doctrine which splits the universe into the living and the dead, no doctrine which requires a God who interferes in His own work, no doctrine which denies the elemental laws of physics and chemistry, is necessary in order that we should recognise life to be something which

EIGHT MILLION HOMES IN AN INCH



BEAUTIFUL HOMES OF LIVING CREATURES BUILT UP IN THE PACIFIC OCEAN

The marvellous power of life is beyond description. In these lovely lace-work shells live creatures so small that eight millions, shells and all, can live together in a cubic inch. These tiny radiolarians live in the Pacific Ocean, and countless myriads die every moment, falling to the ocean bed. There are thousands of species, all marvellously varied in form. The flinty shells are made by the creatures themselves, and through their openings the jelly-like bodies put out feelers to seize food.

is real and separate, whether in grass or in man, though the atoms of the bodies of both were once in the soil and air, and will assuredly be so again. The grass and the man, nevertheless, are real and separate, and so, everywhere and always, is life. It obeys all the earth's laws; it creates no atoms and destroys none; it creates no energy and destroys none; it is part of the earth, born of the earth, and seems to return to the earth as a wave to the sea, but with all this it reconciles and achieves an independence and originality, a purpose and a power which are all its own, and none other's.

Let us be quite sure that this life of which we speak is a very real and very *vital* thing. Science has positive record, in the rocks, of an earthly period when there was no life at all, and life now teems everywhere. It cannot do without certain conditions, but if these be granted its capacities are endless. It was born in water, and all life is lived in water. The sea, and all waters not too salt, are crammed with life to-day. But water contains little oxygen, and life desires intensity, and for that purpose a richer supply of air. It has therefore left the water, probably by the route of the beach—and has established itself in the air, though its primal need for water remains, and every air-breathing thing is within a short time of dying of thirst. The very bird of the air is a manifestation of life living in water—which, indeed, constitutes some three-fourths of its bodily substance—and the blood of man and his allies resembles in its saline composition that of the primitive sea from which man's ancestors emerged. That life, unable to live except in water, should leave its native home for the air, and yet survive, is one of the miracles with which its history abounds

A WATER BEAR
Found alive in large numbers in the ice near the South Pole

LIFE IN THE SNOWS—THE ROTIFERS OF THE ANTARCTIC
These are the little creatures, invisible to the eye, which give the pink tint to the snow near the South Pole; they were photographed by the Shackleton expedition. Neither freezing nor heat near to boiling seems to kill them.

More widely still considered, life presents the spectacle of marching down two great avenues, each of which, in its way, makes for more life and fuller. All except the humblest living things are either plants or animals. Both are equally alive, both are made of cells filled with living protoplasm, both live their lives in water; and without plants there would be no animals. But their vital methods are very different. The plant is content to be just a vegetable, to stay where it finds itself, and feed and breathe on what the movements of soil and wind and water bring to it. The animal is for a shorter and intenser life; and since this involves a special type of food, not everywhere to be found, the animal must go in search of what it needs. These two contrary forms of life are found everywhere—at every level in the sea, in every part of the land, high on the sides of mountains, and the very air is inhabited by birds and insects and the flying seeds of plants, seeking a spot for the life of the new generation.

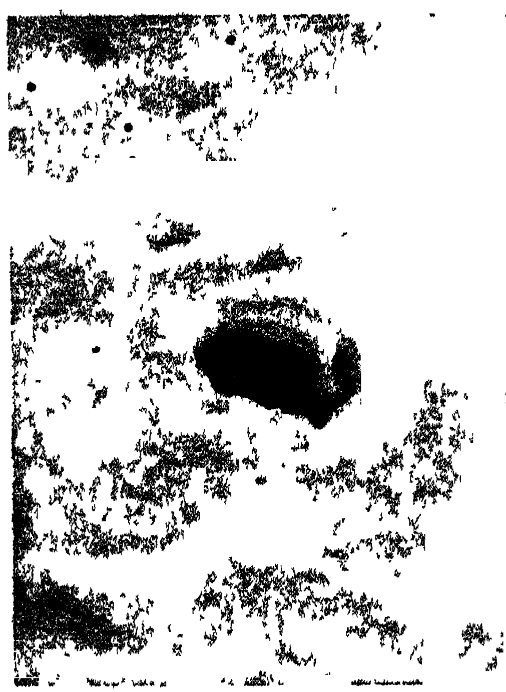
"In two main shapes," says Stevenson, "this eruption covers the countenance of the earth, the animal and the vegetable, one in some degree the inversion of the other, the second rooted to the spot; the first coming detached out of its natal mud, and scurrying abroad with the myriad feet of insects, or towering into the heavens on the wings of a bird—a thing so inconceivable that, if it be well considered, the heart stops. Meanwhile our rotatory island, loaded with predatory life, and more drenched with blood, both animal and vegetable, than ever mutinied ship, scuds through space with unimaginable speed, and turns alternate cheeks to the reverberation of a blazing world, ninety million miles away."

There are eighty thousand kinds of

beetles alone, millions of species of animals and plants, and more are constantly coming into existence as life discovers new possibilities. The total number of living individuals is utterly inconceivable if we consider the present only, and immeasurably more so if we include the past. Out of apparent nothingness and night came this irresistible, incomparable thing, of which it may well be that we see the merest beginning.

All things move—rocks and crystals grow; living things move and grow, too. Vital growth is achieved by the intake into the living substance of materials which it endows with life, or uses for the purposes of life. And growing, living things develop, which is a deed all their own. All individual bodies, whether a moss or a microbe or a man, are destined to die—as individuals. But they are endowed with the powers of reproduction or parenthood, which is another of the unique and inimitable marks of life. And living things may be moved, as other things may be, but they are also capable of movements which, though ever obedient to the laws of physics, are unique in their purpose and their originality. Water runs downhill but the heart pumps the blood uphill and down, wherever it is wanted. Light exercises a repelling force in all directions and upon everything material, but the living moth flies towards it. An avalanche, nay, the earth itself, moves as it is moved, taking the easiest course, but a soldier or a mother, nay, an old male baboon, will climb uphill to certain death, will venture among the deadliest foes, to save their young. There is nothing that life will not dare for life.

It is true that we may later learn how closely some of the attributes of life may be displayed in its absence. The study of ferments teaches us that the gap between the living and the not-living is no breach in Nature's continuity, did we but know. All this we must study, but not without realising that the characteristics of life are not thereby diminished nor denied, any more than the plays of Shakespeare are discredited because he was once a baby. Things are what they are, no matter how completely we can trace their origin and connections. Fools, it is true, may marvel at them less, but the wise will marvel more. The student of life, who must necessarily be the admirer of life, need not suppose that the lark's song and flight, or the splendour of the rose, would be less than they are even supposing that man should succeed in manufacturing larks or roses in the laboratory tomorrow. So much the better for him, but why the worse for them? We may rightly rhapsodise over life while we manufacture artificial life in the laboratory—if we can; and as we shall some day.



"WHEREVER MAN GOES, THERE LIFE HAS BEEN BEFORE HIM"

A penguin in the snows of the Antarctic—from a photograph.

As we witness and wonder, one question forces itself more and more upon us. The push, the "go," the tireless thrust, the inexhaustible resource of life—for what are they? Is life as such, in whatever form, an end in itself, or is it a means to an end?

These may be questions which we cannot answer, but it is better to have asked in vain than never to have asked at all, and the answers will yet be found.

Certainly the proximate purposes of life can be discerned. In Tennyson's phrase, it is "more life and fuller" that all living things want. Whether intensively or extensively, life is always asking for more. Its courage and initiative and resource, its incapacity to know when it is beaten, and its unfailing resurrections, these are definitely engaged in seeking the constant end of all forms of life—more life and fuller. In general the proposition may be laid down that the method of "extensive culture" always tends to be succeeded by that of "intensive culture"—to borrow terms from the farmer. Life begins by taking hold everywhere, from the mountain side to the

depths of the ocean, over hill, over dale. Every species is a champion of life. Species may fight and eat each other in an apparently mad and wasteful fashion, but one and all are for the common end more life.

Thus there gradually emerges a greater intensity in the areas already covered—as a first stage, so to say—by life of lower intensity. The animal world supervenes upon the vegetable. Active fish follow after the seaweed, birds surpass insects, restless, quick-eyed carnivors tend to supersede the lower mammalian forms which munch grass all the day, until at last there appears the most intense and restless and insatiable and hungry and inventive of all living beings, man himself, who is the master and the terror of all other beings—except, for a few more years, certain parasites—and who alone, of all living forms, increases in numbers. He leads the "fuller" life indeed, and as he conquers the continents he realises the poet's phrase, making more life as well as fuller. And even in this dominant species the conquest and the future are always to the most active, the most intense—those who lead the fullest life.

The Great Purpose of all Life is the Making of More Life

We see the making of more life to be the immediate purpose of all life, and yet we are everywhere faced with the facts of death and murder and struggle and disease and starvation. If the young of the bird are to be fed, many insects must die; if man is to have bread, countless millions of young wheat-embryos must be sacrificed; the big fishes eat the little fishes, and these the lesser still. This "struggle for life," or "struggle for existence," is one of the great facts of the living world; and only in the nineteenth century did men come to see that it could be interpreted as serving the purpose of life, even through this incessant spectacle of murder and death.

More astonishing still, while Darwin was explaining to us the struggle for existence, Pasteur showed that by far the greater part of all our diseases are due to nothing else than a struggle for existence between humble forms of life—mostly vegetable—and our own. In fact, one of the modes by which life seeks to extend itself is the paradoxical mode of parasitism, which we find to be a general fact of the living world, and one of the most widespread and constant forms of the struggle for existence. Every new form of life is a chance for some other form of life to employ for its purposes, and thus the evolution of new forms leads to the corresponding development of new forms of parasites.

Practically the whole of disease thus takes an entirely new form in our mind's eye. It is part of evolution, part of the struggle for existence. An attack of pneumonia is simply the rapid multiplication, in suitable conditions of temperature and food supply, of a particular form of simple plant which takes the opportunity of multiplying, as every living thing would do in similar circumstances. It is now life against life; incomparable man, battling with his chemical weapons against those of the parasitic vegetable which has found him a suitable home for itself and its children.

Man's Great Struggle Against the Living Enemies of Life

While some impartial point of view can be imagined from which the issue of this contest would be a matter of no concern, yet it is clear to us that the life of the man is high, and that of the parasite is low. Further, we are entitled to discover in all parasitism whatever, whether it affects us directly or not, a form of degeneration. In this struggle, therefore, our sympathies are with man and against the parasite; and parasites in general, though themselves alive and fighting for their lives, may be looked upon as the enemies of life, since they are degenerate, and their lives lead to nothing but the destruction of higher living forms.

Thus it will be necessary for us to study the great world-processes of disease from this vital point of view, and to review the amazing fashion in which the highest form of life, which we call man, is establishing its hold upon the earth, and learning to exterminate those lower forms which are the only living creatures that have not yet come completely under his sway.

The Profound Truth of Science Spoken by the Greatest of Teachers

In this, as in so many other respects, man demonstrates himself to be a part of living Nature, but the part which displays the characteristics of life in their most marked form. There is no other key to the behaviour, the structure, the living and the dying, the selfishness and the unselfishness of living things but this: they are made to magnify and amplify life, directly or indirectly, in their own persons or in those of their descendants; and that which is true of all other living forms, in their lowest as

well as their highest manifestations is true also of man, and of man in all his aspects. Thus from the standpoint of the science of life no deeper or profounder words were ever spoken than those in which the greatest of Teachers said: "I am come that ye might have life, and that ye might have it more abundantly."

The answer which is so clearly given by the unanimous voice of living Nature from the lowest to the highest, and to which every attribute and character of every living thing and even of death bears witness, is only a proximate answer. More life and fuller is the purpose of all life; but is that all in all?

Are we really to regard the presence and maintenance of life, any kind of life, as an end in itself?

Though much is to be said for that view, it does not satisfy us. Indeed, life is never satisfied; its motto is ever "Excelsior." Himself, and practising the doctrine of "art for art's sake," as if to say the rose will die, but till then it is a rose, and beauty needs no further warrant for its existence?

Few there will be to content themselves with such an explanation. If, indeed, the history of the living world be a work of art, we cannot admit that it is finished. Plainly it is not finished, as witness the struggle and striving of the life of man. The warnings of the astronomers suggest that the story must come to an end some day. What end, then? And what of the countless millions who have lived and died without knowing or even imagining it?

It were wiser to be humble and silent, rather than essay answers to such questions as these. At times we may feel as Macbeth did when all was lost—expressed in that image of drama suiting the case so well:

To-morrow, and to-morrow, and to-morrow
Creeps in its petty pace from day to day,

FOR MILLIONS OF YEARS LIFE CREPT INTO THINGS OF ALL SORTS AND SHAPES

These pictures show three strange forms of life: (1) the bull-headed frog of East Africa, (2) the seaweed-like sea-horse found in Australian waters, (3) a sea spider like an umbrella found in the Atlantic and Pacific Oceans

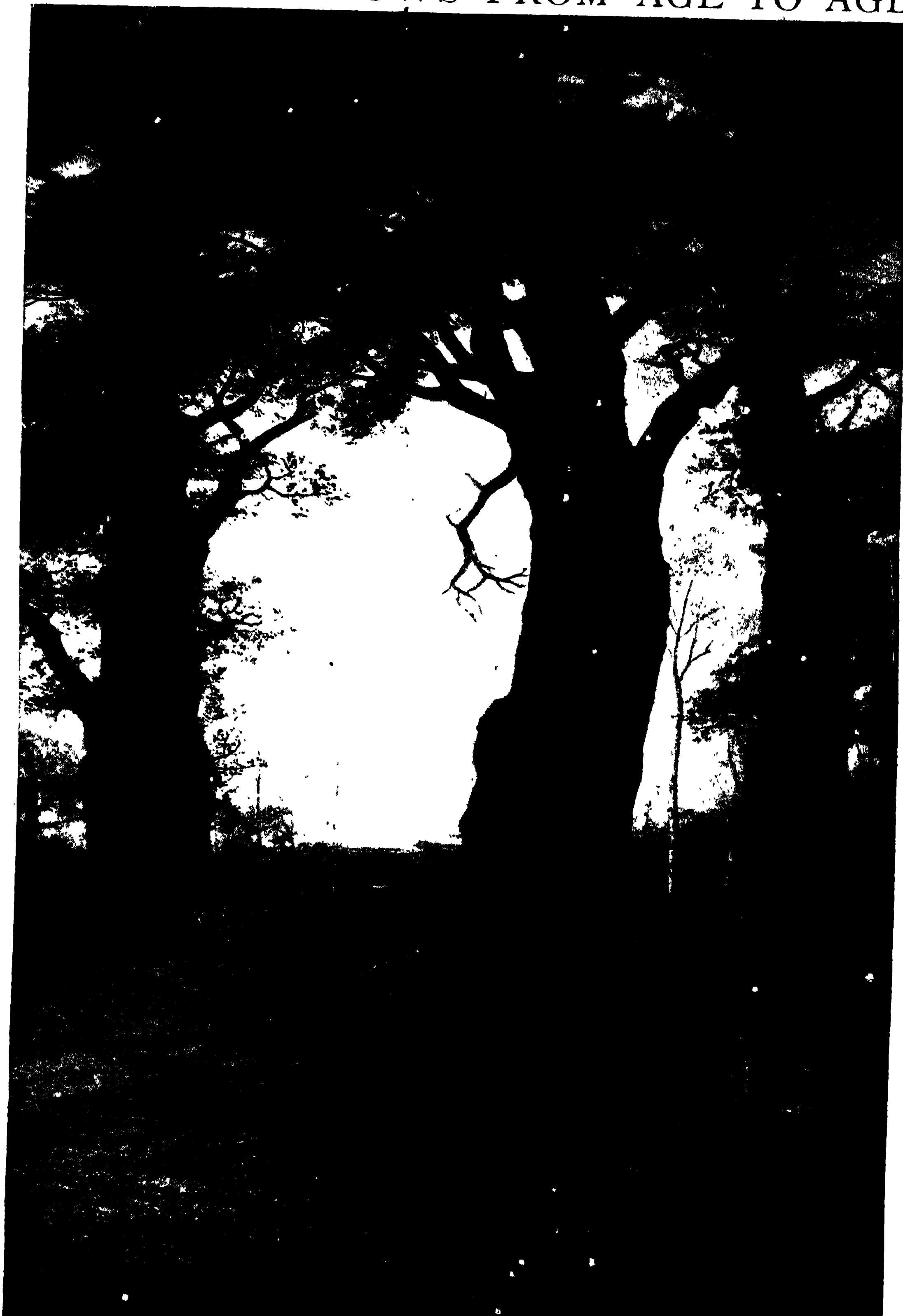
and we who are now in the van, and who climb as all our predecessors have done, want to know the goal towards which we climb. A hundred years ago, when men believed that all forms of life, high and low, intense and self-conscious, sluggish and asleep, had been separately created as they were, there could not arise the question which can never leave the mind of the evolutionist to-day. He sees that life ascends; he has observed the historical fact and progress. Once there were no brains upon the earth; once there was no motherhood. Reason and love have come out of the struggle, and they struggle still. Surely there must be some "far-off divine event to which the whole creation moves." Or is it rather that the Author is an artist who makes wonderful and lovely things, ever learning by experience and excelling

To the last syllable of recorded time;
And all our yesterdays have lighted fools
The way to dusty death. Out, out, brief candle!
Life's but a walking shadow, a poor player
That struts and frets his hour upon the stage,
And then is heard no more. It is a tale
Told by an idiot, full of sound and fury,
Signifying nothing!

But faith and hope and courage and imagination are attributes of life, as we display and feel it; they have their warrant as eyes and hands have; and in virtue of them we may say with Tennyson:

At first, this earth, a stage so gloomed with woe,
You all but sicken at the shifting scenes.
And yet be patient. Our playwright may show
In some fifth act what this wild drama means.

LIFE THAT GROWS FROM AGE TO AGE



The "bare ruined choirs where late the sweet birds sang" are shown with vivid touch in this splendid picture by Mr. MacWhirter, who gave it the happy title of "The Three Kings"

THE EARTH'S INVISIBLE ARMY

The Battles that no Eye can see, which make Gardens and Forests, and Keep the Earth Alive

LIFE ON THE EDGE OF TWO KINGDOMS

No discovery for very long time, perhaps none ever, has opened more vistas to the imagination, or made so much difference in our way of regarding many of the common things of life, as Pasteur's proofs that life is present almost everywhere, in almost everything.

Within our bodies, and all parts of our bodies, are living things innumerable, fighting one another; and as the better or the worse win, so our health is good or bad, so we live or die. Pasteur was chiefly concerned with the life and the struggle for life that went on in the bodies of animals; but his discoveries added much energy and interest to the men of science who began to be engaged in the study of the earth. Just about a generation ago they came to see that the health of plants, like the health of man, depended on certain forms of life invisible to the naked eye, living, however, not within the plant, except in certain cases, but in the soil.

Recently these agricultural discoverers, if they may be called so, have made a number of new discoveries of the reason of fertility in soil; and roughly, for the moment, these may be put under two heads. They have proved that most plants thrive or fail to thrive owing to the presence and activity of two sorts of living things in the soil. One of these is the class of funguses, some of which cling to the roots and supply food to the plants; the others, more important, are bacteria. Both are often spoken of as the "flora" of the soil, on the assumption that they are both botanical rather than zoological.

These flora are all of cardinal importance to anyone who grows anything. They are important also in many industries, in cheese-making, for example, even in butter-making, and they are specially cultivated for these purposes. But for the moment the fungus may be set aside and the bacteria only considered, as they affect the farmer and gardener, and incidentally as they affect all of us who are interested in the marvels of the world about us and under our feet. Indeed, the world has become to our fancy a much more wonderful place, even in the last two or three years, since we have known of the astounding activity of life beneath our feet, both its warfare and its industries.

It may be added that science itself has become more exciting, for we seem to be clearly on the edge of further wonders. But these wonders also affect our wealth and comfort very closely. Through all ages, since men gave up the pure nomad life, agriculture has been the most important of all industries, but until this generation it was not in the least known why soil was fertile. Farmers knew with surprising accuracy what things increased fertility. The practical knowledge has not increased enormously. Virgil and Pliny, for example, knew that clover, instead of taking good out of the soil, as other crops do, actually improved the soil. The uses of manure and leaf-mould have been well understood. To a less degree farmers have always known that good results followed aeration of the soil and deep cultivation.

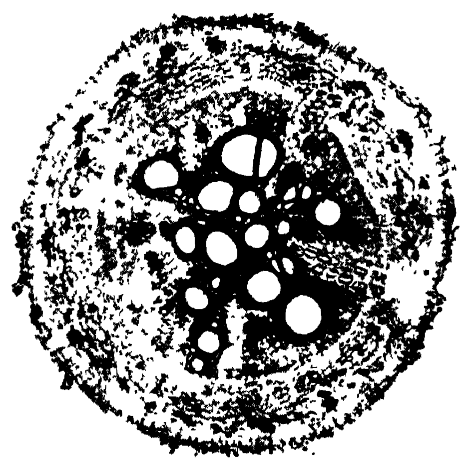
But until quite recently nobody even suspected the chief cause of fertility. It is only within this century that they have known with any fulness of proof how fertility is procured, and we may expect new and remarkable additions to our knowledge within the next few years. A clod of earth has always been regarded as a singularly lifeless thing. A lifeless clod is almost a proverbial phrase; and the clods of all cultivated fields were treated as lifeless. They had to be broken up, and

nto the cultivated earth had to be put a certain amount of vegetable stuff, either decayed or green. That is, farmers, as will always be the case, in all probability, either put manure on the land or ploughed into the land a growing green crop, such as clover, or mustard, or what not. But now the followers of Pasteur, whose discoveries made a revolution in all science, have demonstrated that a clod, so far from being lifeless, teems with life. In any square inch of fertile top soil are colonies of bacteria whose numbers are reckoned in millions.

It is an astounding thought that this mass of life is under our foot, that the bit of earth between our fingers contains thousands, if not millions, of organisms which a microscope can show distinctly. It is still a question whether bacteria are to be called animal or vegetable, but of late the botanists have been making good their claims. The bacteria on the edge of the two kingdoms, and their presence and nature, might incline an imaginative person to believe in the old theory of "spontaneous generation," by which, ultimately, inorganic or mineral stuff might become organic or living. But that is of no matter: what is of matter is that every farmer and gardener must now recognise the presence of all this life in the "lifeless clod" and act so as to encourage it.

Of course, other things are also of importance in the clod. In the first place it has to consist of certain chemical substances, or else the plant will die of starvation of its standard food. One of the really great advances in farming was the demonstration, by Mr. Lawes, in the middle of last century, that these chemicals could be supplied directly. He started the whole trade of artificial manures, and incidentally made a small fortune. Of this fortune he devoted a good part to the founding of an institution where the soil should be studied. This institution, established near Harpenden, in Hertfordshire, is known as the Rothamsted Experimental Farm, and in 1909 a startling discovery in regard to bacteria was made there, a discovery that would have astounded the founder. The chemical substances in the soil are one essential point. Another is the consistency of the soil, its texture and closeness. Sand is barren not only because it consists mostly of a half-useless substance, but because its particles are big and let the water through easily. The sort of soil most different from sand is clay. This contains almost everything that most plants require, but it is often barren enough because the particles are so exceedingly fine, and the consistency consequently so close, that neither water nor air can find a way into it anyhow.

Previously, then, students used to consider a clod under two aspects only: its chemistry—the chemical substances out of which it is composed—and its mechanical structure. Now they add a third, its biology, or the life which it contains; and this third is, perhaps, the most important of all facts concerning the soil that we have to consider. Certainly it is the most fascinating; and the workers of the world are united in a hot hunt after the new mysteries. Discoveries succeed one another rapidly, and each opens up new possibilities of adding to the fertility of the ground, and therefore the wealth and probable happiness of mankind.

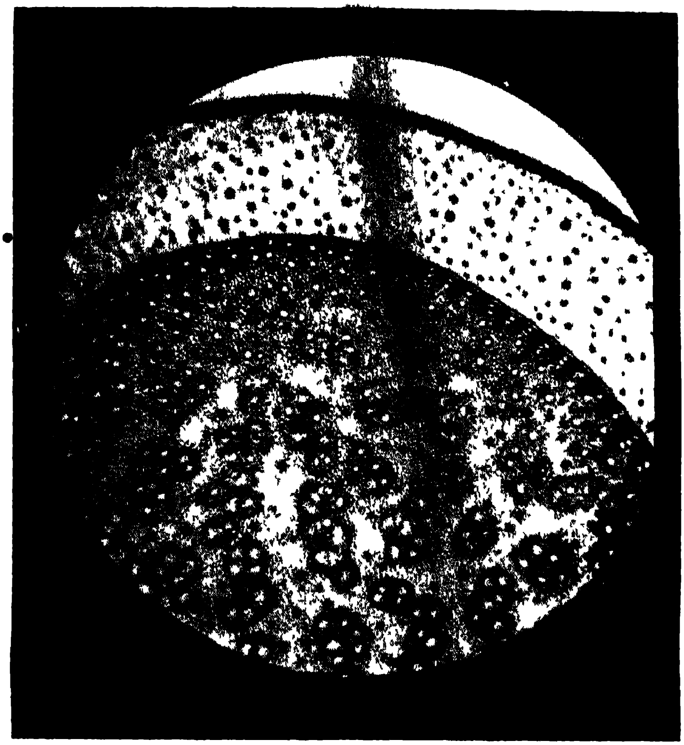


ROOT OF A BEAN: A MICROSCOPIC PHOTOGRAPH

The struggle for life, which Darwin and Wallace made clear and made popular, grows more and more tremendous the lower we go into the scale of life. It is fairly severe among men, but it becomes a Titanic warfare in the clods under our feet, waged between millions of these organisms which are neither animal nor vegetable, or perhaps more truly are both; and whether the fortune of war inclines to "the side of the angels," or beneficent bacteria, or the side of the malefactors, depends a great deal on the good or bad sense of the husbandman.

Everything that lives, and every variety of everything that lives, has what botanists call "an optimum"—that is, a set of circumstances which favour it more than they favour anything else. Given certain supplies of ammonia, even tender grasses will kill

out the plantains. Withhold ammonia, and the plantains will drive out most of the grasses. The same thing happens underground. There is a perpetual and deadly fight between what, from our point of view, are good and bad organisms. A very beautiful series of experiments made recently at Rothamsted show how the war may be waged. A quantity of soil, in which the bacteria were counted, was sterilised by boiling, the intention being to kill the bacteria so that it might be seen how ill or well plants grew without their aid. It was found, to the great surprise of the experimenters, that the plants, though they did very badly at first, growing very slowly, afterwards grew a good deal faster and better than in the original soil. The surprise vanished, however, and was succeeded by another and greater surprise, when it was found that the soil in which it had been thought the bacteria were killed was, in fact, swarming with a double number.



A BEAUTIFUL THING THAT WORKS IN THE EARTH

A microscopic photograph of a section through the root of a cabbage, showing the marvellously complex structure by which the plant absorbs the elements.

How had this happened? The present belief is this: In the warfare in the soil the bacteria are conquered and devoured by the more highly developed organisms, known as protozoa. The heating of the soil had killed all the protozoa, but had left a few of the bacteria. These, increasing at the astounding speed of which they are capable, had flourished beyond measure in the complete absence of their worst enemy. Until their numbers were sufficient the plant had languished, and had flourished in double measure when these assistants had doubled.

This experiment does more than suggest the details of a perpetual warfare. It proves, with a thousand other experiments, that the fertility of the clod is chiefly dependent on the "flora" that it contains. The earth to the plant is like the sea to the Ancient Mariner: "Water, water everywhere, but not a drop to drink!" It is full of food that a plant requires from the land—it must never be forgotten how much the plant requires, not of the land, but of the sun—but the plant cannot use it. A field in which manure is heaped year after year, yet which, nevertheless, lacks a good deal of fertility, may be a perfect storehouse of food, with supplies sufficient for years. But these supplies are no sort of good unless they are reduced to the proper state in which the plant can assimilate them. Indeed, the wealthiest soils, in one sense, may be the most barren. Perhaps the most wonderful practical demonstration of this is to be seen in the east of Prussia.

Vast tracks of rough and barren heath-land had been left rough and barren, though, as any chemist could have told, the land was full not only of inorganic food for plants, but of valuable humus or vegetable fibre in a certain condition. Efforts to make this desert profitable all failed till the discovery of the vast population of the ground was applied in practical form. These tracts were found to be without the beneficent bacteria, and perhaps without fungus. In consequence, the roots and stems of what plants grew and died there did not decay and rot, as they would on a cultivated field. They became, instead, a sort of peat. One might divide the land of the world up into two divisions: one where buried vegetation decays, to the great advantage of all that is grown there; the other where it becomes some sort of peat, reaching a condition in which the fibres are more or less well preserved

or unburnt, or, at any rate, unconverted into plant food. Exactly as theory would suggest, these barren lands wanted only the right underground population. It was not enough to cause a migration, merely to set down a colony of the right cultivators. They would have been starved out or killed in competition with the existing population. Indeed, the reason why the barren tracts were without beneficent bacteria was that the soil did not agree with them.

The Invisible Cultivators without whose Help Man is as Nothing

There are bacteria which can flourish in the absence of air, and some of these are of prime importance in the making of the world's surface; but the farmers' friends demand a good many conditions if they are to flourish, including air and water, and the absence of acidity. Above all else, oxygen excepted, they are quite unable to live or work without a sufficiency of some "base," which for practical purposes may be called lime or chalk. The barrens had to be ploughed and harrowed, they had to be limed, but this double process was doomed to be useless by itself, as previous experimenters had found. We may practise the best possible mechanical means that science suggests, such as deep cultivating and careful harrowing; we may practise the best possible chemical means, such as adding to the soil the constituents which it needs, or such as correcting or neutralising the acids with alkalies, but the precautions will be useless unless we also make use of the invisible cultivators. The most remarkable experiences in Germany followed the treating of the land with small amounts of earth from cultivated fields. Some similar experiences have been recorded in Ireland, but the results there were more doubtful.

Can we Persuade the Invisible Workers to Change their Habits?

One of the great problems of the time is to discover whether these "cultivators" can be bred in the laboratory. It is clearly very much easier to introduce into the soil a phialful of bacteria than to cart earth from perhaps distant fields, but it is still not quite clearly proved how far this is possible. The bacteria sent to South Africa from America failed, on the whole; it was said because they had grown "lazy." The word is not perhaps altogether scientific, but it meant this: For one reason or another the bacteria began to lose their special activity—one may say skill; and it may be that one reason of this was that they obtained their supplies too easily. In a word, they indeed grew lazy.

However, a great advance has been made recently, notably in the making of recipes of material in which the bacteria can be cultivated. Cultures in certain media have been very successful, and probably the time is coming when the laboratories will be able to supply the right sort of bacteria, as an emigration bureau promises to supply the right type of colonist. Some men of science have claimed that they can actually change the habits of bacteria, and make them bring fertility to other plants than those which they naturally affect. How this could be achieved, and what it would mean, may be explained when the particular class of bacteria come under discussion. But it may be said here that if it could be proved, for example, that nitrogen-fixing bacteria which normally live on the roots of leguminous plants only—beans, clover, and the like—could be induced to live also on the roots of strawberries—as was claimed—the increase of crops might, perhaps, be enormously extended. This is a possible theory, but it has not yet been proved.

What Happens to a Branch when it Falls to the Ground

Every practical farmer or gardener, then, as well as the student, must think of the soil as a place full of life, and recognise that the amount of his crops will depend very largely on the way in which he encourages the living things. Hoeing and ploughing and harrowing all affect these organisms in a vital degree. The adding of lime to the soil, which is one of the most important farming operations, especially affects them. So does manure or the ploughing of green crops into the ground.

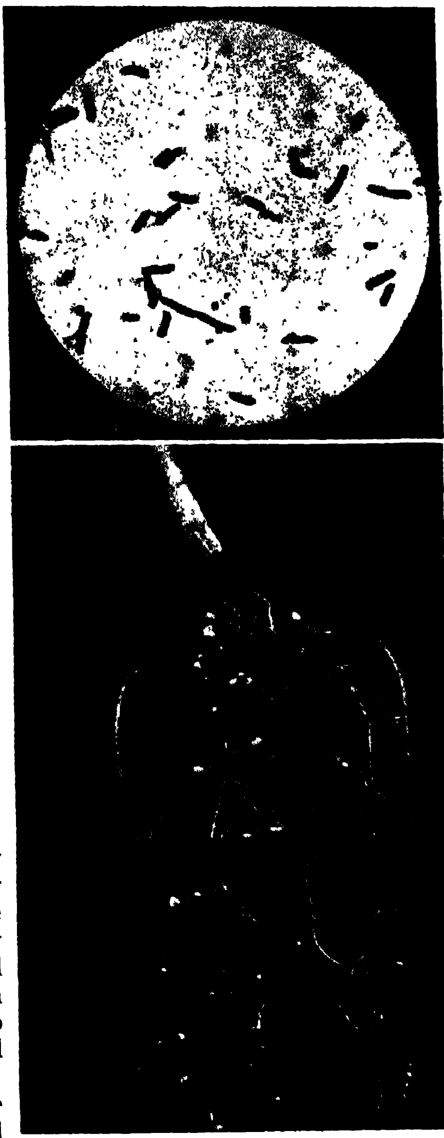
What is the direct work that these organisms do? We all know that when leaves, or even the boughs of a tree, fall on to the ground, they soon lose their shape and consistency. They are, in short, changed to something else. But there is no necessity in the nature of things that they should be broken up. Someone has compared the breaking up of a piece of dead bough to the act of burning. If we burn a bit of wood, it disappears into other things, into gases and soot and a filmy ash. Pick up a very much decayed twig, and it will be as light as a feather, and very likely fall to pieces in the hand, becoming a sort of ash.

Like the burnt twig, it has been changed into other things, and some of it has gone off in gases. The roots and stubble of corn, the ploughed-in weeds and manures,

disappear or change in just such a manner. On the other hand, if a bough is sunk under the mud of a pond, it may be preserved almost as well as if it were soaked through with creosote or tar. Much the same thing may happen to the roots of heather and other things growing on some barren heath. In other words, to keep up our comparison, in one case a light has been set to the wood, and in the other case it has not. But the light in question is a living thing.

All organic — that is, living—stuff, when it dies and is left anywhere near the surface, is broken up, and is decomposed by other living things which change its nature and consistency, even more fully than the worm changes the leaves which it continually passes through its body. These living things, though they are so small as to be invisible, and so numerous as to be uncountable, except in hundreds, flourish much as highly developed organisms flourish. That is to say, they must breathe and they must eat. More precisely, they need oxygen and they need carbo-hydrates or some form of sugar. One might go further and say that, like man, they need a change. To make them travel from one part to another of the same field increases their vigour.

There are some people now farming in a practical manner, though on a small scale, who principally fertilise their fields by sprinkling earth from one field on to another. Further, these living things in the soil must live, so to speak, in a temperate clime; or, in other words, they like a particular temperature, and cease to flourish the moment it is much diminished or reduced. The actual heat that they prefer is very much what many people prefer—between 60 and 70 degrees Fahrenheit.



NITROGEN "FACTORIES" AND WORKERS

It had long been known that the little nodules on the roots of certain plants increased the fertility of the soil, but it was not until twenty-five years ago that the cause was discovered. It is now known that these nodules are full of invisible creatures—magnified a thousand times in the top picture—which have the power of absorbing nitrogen from the air. The nitrogen is stored up in the nodules, which thus become a source of life-giving power to the plant.

Some sorts of bacteria can live without oxygen, and of these something has to be said, but the beneficent bacteria which make fertile crops possible need such conditions as have been described; and cultivation from the beginning of time has been designed to give these organisms the air and food they require, though it was not suspected till about 1875 that this cultivation had any such effect, or even that there existed in the soil organisms to be considered. A countryman could scarcely read a book of more continued interest, scientifically and practically, than Darwin's "Earthworms," which do so vast a work in fertilising and changing the surface of the country. But the bacteria, of which Darwin had scarcely a suspicion, are of a thousand times more importance to the world. We could do without worms, but we could not do without bacteria.

The reason why we could not do without bacteria is becoming less obscure year by year. Up to a certain point, it is clear enough. One of the things that plants need absolutely is nitrogen, and they can only get it through their roots. A great man of science once foretold the ultimate starving out of the world owing to the disappearance of the stores of nitrogen, or plant food. We now know that there is no fear of this starvation, but his gloomy prophecy indicates the essential nature of the plant food. If we see corn or almost anything else grow yellow in the country, it is due to nitrogen-starvation, and directly it is properly fed with nitrogen the good healthy green colour returns to it. But the trouble is that

SEVEN STEPS IN THE CYCLE OF LIFE

STEP 1
A seed builds up a plant

STEP 2
Plant life grows and builds up animal life

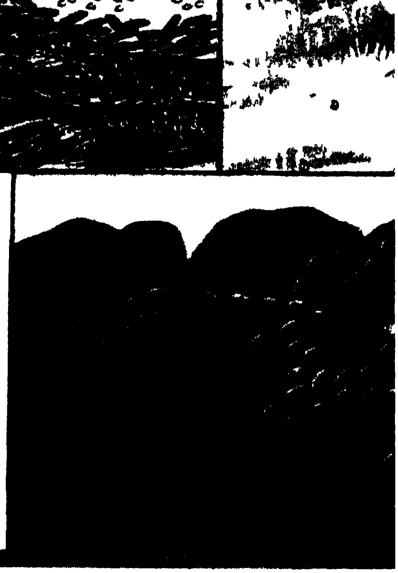
STEP 3
The animal dies and bacteria convert it into simple nitrogen, some escaping into air and some returning to the soil

STEP 4
Other bacteria build up th

It is not easy to think of anything more wonderful than the endless cycle of life by which the vital power of the human race is sustained. We may divide the cycle into seven steps.

The first shows the seed packed with the vital force of life, generating the root which absorbs the elements of soil and air, so building up a plant.

The second step shows the animals which eat the plant, so sustaining themselves and producing offspring by means of the complex products the plant creates.



The animal dies, and the third step shows the beginning of the marvellous scheme by which the earth wins back for itself the vital force taken from it by the plants. The dead body of the animal is attacked by a colony of bacteria, with other agents of putrefaction, which decompose the animal matter and convert it into nitrogen, part of which escapes into the air as free nitrogen, while the other part returns to the earth in the form known as nitrites.

Though back in the earth again, the nitrogen in the form of nitrites is too simple in kind to be of use to plants, and the fourth step is the appearance upon the scene of another colony of bacteria, working upon the nitrites so as to build

These pictures are drawn to convey a graphic idea of the cycle of life, usually illustrated in diagram form, and though they represent

THAT SUSTAINS THE HUMAN RACE

nitrogen in the soil ... to plant food

STEP 5

A third group of bacteria capture the free nitrogen from the air, storing it in nodules on root of plant

STEP 6

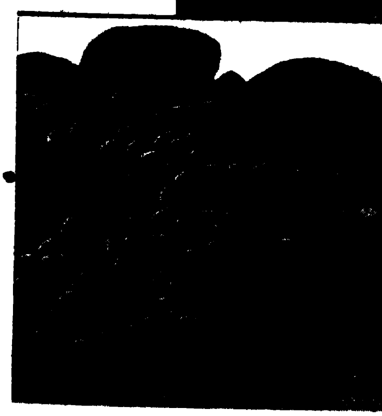
The nitrogen builds up plant again

STEP 7

The soil enriched by nitrogen nourishes wheat, the staple food of man

them up richer in oxygen, in the form of nitrates, which the plant can use.

Into the fifth step comes a third colony of bacteria, which, in some marvellous way unknown to man, recover the nitrogen that escaped into air. This they store in little nodules which they make on the root. In these nodules live these amazing creatures, the last link uniting the animal to the vegetable world.



The earth having now recovered its lost nitrogen, with the aid of its invisible army of bacteria, becomes richer in nitrates, and the sixth step shows the plant growing again.

But what we may call the seventh step, and the last, is perhaps the most astonishing part of all this astonishing tale of life. It explains what the farmer means when he speaks of rotation of crops. A wheatfield sown with clover one year is vastly richer in wheat the next, because, though the nodules feed the plant, they remain in the soil and give up the vital power to the next crop of wheat.

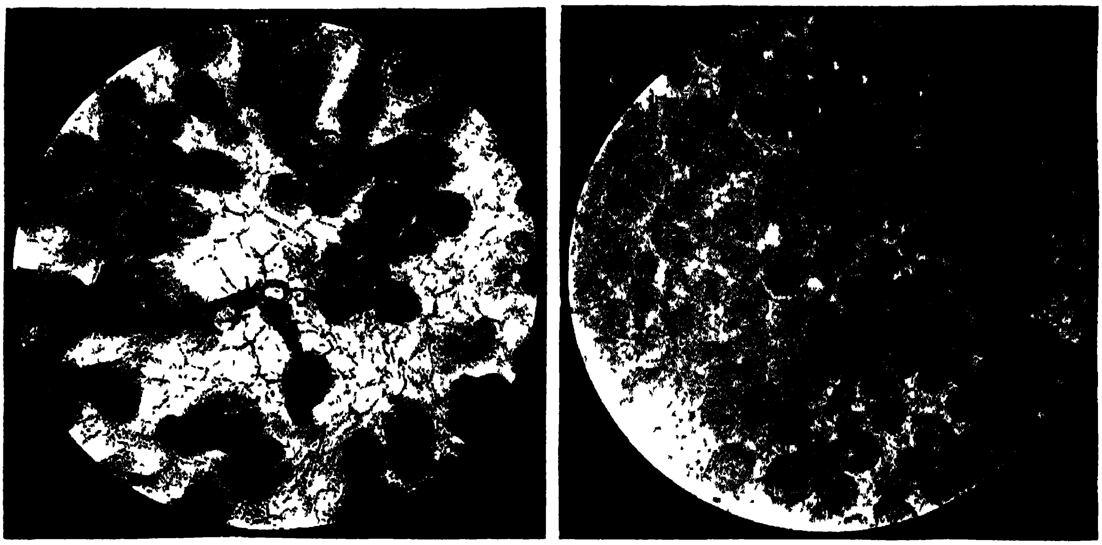
So, in these seven steps, the cycle of life is complete. From plant to animal and from animal to plant, conveyed by an army of creatures apparently on the edge of the two kingdoms, life runs its circle and upholds the human race.

actual stages and processes of growth, they are, of course, without regard to scale, and represent invisible things, such as nitrogen

plants will only take their nitrogen in a particular form. They will starve in the midst of plenty unless their food, the nitrogen, is in a particular form. Their food, so to speak, must be predigested. Speaking generally, nitrogen can only be absorbed by plants in the form of nitric acid or nitrate; the work of the bacteria which have chiefly been studied is to supply this form of nitrogen to the soil.

What they do is to seize upon the various compounds of nitrogen supplied to the soil, and break them up into simpler compounds, the last of which is nitric acid. In this work there is much sub-division of labour, one species of bacteria doing one part of the work, one another. A special study has been made of the bacteria which are concerned with the two final steps. One species changes or oxidises the ammonia into nitrous acid, the other oxidises the nitrous acid into nitric acid. It is a sufficiently marvellous fact that these particular sorts of bacteria have been found in the fertile soils of almost every country in the world. For example, Mr. A. D. Hall, the director of the Rothamsted Experimental Station, has himself found bacteria of an identical form in virgin soils from East Africa, India, New Zealand, Egypt, Russia, Monte Video, Ohio, and Sarawak.

Those facts help to explain a number of practical facts about which farmers and others have many superstitions or contrary beliefs. Mr. Hall, in his admirable text-book on the soil, shows why corn is apt, as all farmers know, to turn yellow when there is a long spell of cold north and easterly wind. The reason is not that the wind cuts the plant, or even that it lessens the moisture in the soil. The plants go yellow because their roots are not supplied with sufficient nitrogen, just as men grow pale or languid if they omit any of the proper constituents of their food. They are starved of nitrogen solely for this reason: that the bacteria do not flourish in cold soil, but return to vigour when the warmth increases; and as they return to vigour the corn becomes green again. It is, in short, feeding itself on the nitrates which have themselves been brought down to the digestible state by the beneficent bacteria.



A MICROSCOPIC PHOTOGRAPH SHOWING BACTERIA AT WORK IN THE NODULE OF A PLANT

The first of these photographs shows the bacteria at work in the "nitrogen factories" which they build on the roots of plants in the form of nodules, as shown on page 41 The bacteria are the dark patches filling the cells; the two larger creatures are intruders These marvellous bacteria are the only living things on the earth which have the power of obtaining nitrogen from the air, and they store the nitrogen in the nodules for the plant to use. The dark spots in the second picture indicate the change during nitrification. These photographs were taken at the Horticultural College for Women, at Hextable, Kent

Another delightfully practical example is given in the same place. Turnips are a crop which take up a very large amount of nitrogen. Nitrogen disappears from the top soil at a very great rate in the months when the crop is growing fast; and the quantity of nitrogen taken away by the crop can be directly tested. All this has been known for a long time. But, in spite of the knowledge, it has not been customary, nor is it now customary, for farmers to use much nitrogenous manure for their turnip crop, and in practice the crop does quite well without it.

How can this be? The habits of the bacteria explain it all. It must be remembered that the soil is a rich storehouse of

food; even the poorer soils are full of plant-wealth. And the chief problem is not so much to increase that wealth as to make it available—to mint it, as it were. In the case of the turnips it is minted indirectly by the cultivation, directly by the bacteria. The frequent and careful surface cultivation swarm and aerates the soil so admirably that the bacteria multiply to their maximum. All conditions favour them in their struggle for life. Where they flourish the turnips flourish, for they spend their vigour in converting the stores of nitrogen into the form in which the turnip plant can eat it up.

GROWTH WITH & WITHOUT INOCULATION

Professor Bottomley has for years been experimenting in treatment of the soil for increasing its fertility, and the principle of his treatment is to infuse into the soil the bacteria which have the power of obtaining nitrogen from the air and storing it in the nodules of the plant. This picture shows the difference between turnips grown after inoculation by the professor's method and turnips grown without it, the increased size being due to his treatment

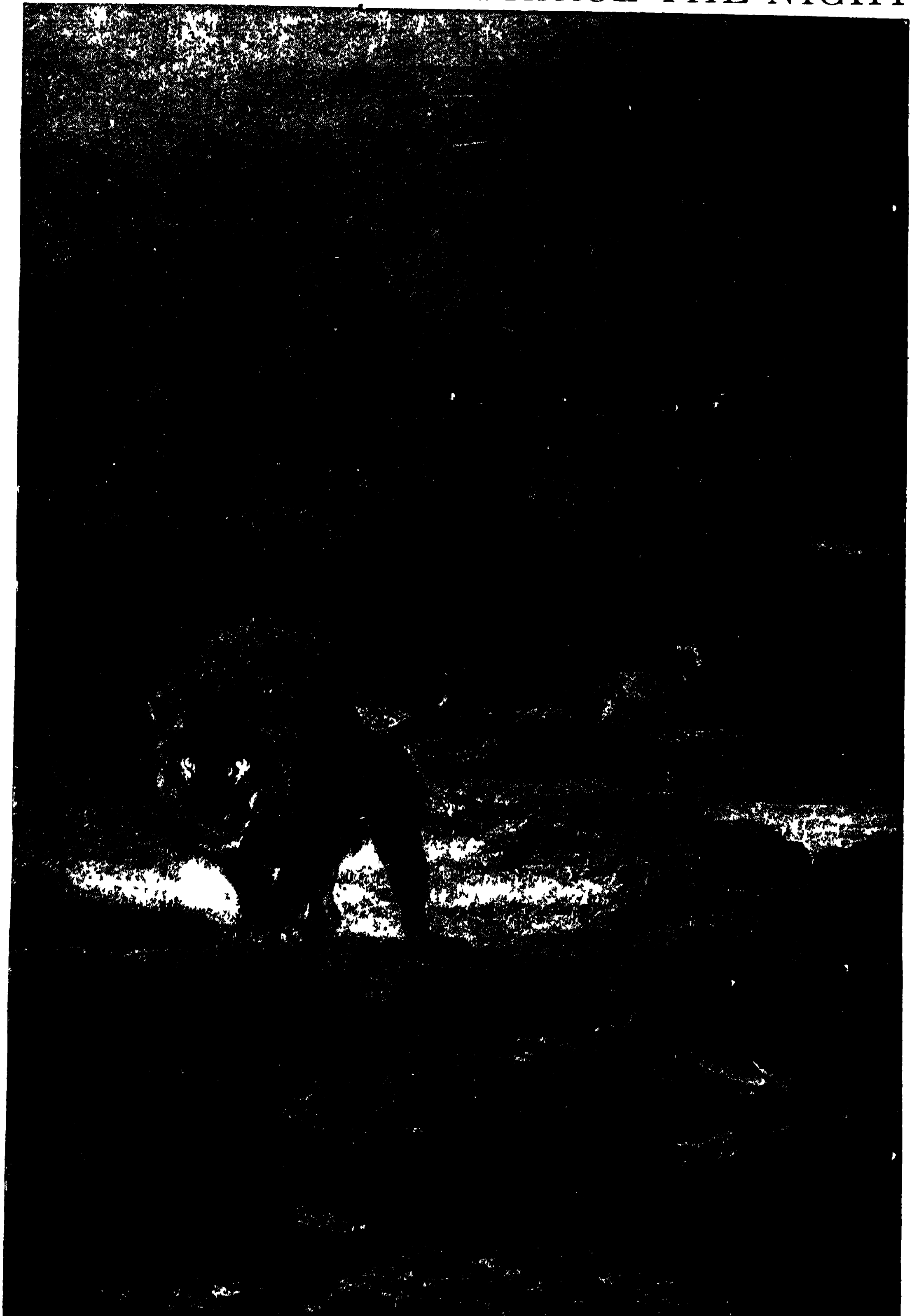
To give another instance, the virgin soils of Canada, and of other countries, described sometimes as inexhaustible, are not rich chiefly because they have a great depth of organic material. The real reason is that for centuries bacteria have been working in the food supplied to them, and they have left vast stores of the nitrates that the crops demand. The bacteria have had the right food supplied to them, and they, in turn, have handed on other food to the plants.

It is impossible to arrive at even a general view of the value of these little organisms without considering one especial class. Men of science have been puzzled for generations to account for the increase of nitrogen in the soil. It was long suspected that the puzzle was in some vague way connected with the leguminous plants. In every country, for many hundred years, farmers have noticed that a crop of clover or similar plant, instead of taking good out of the land, as we should expect, added wealth to it. Now, a peculiarity of clover and leguminous plants is that they have little nodules, small but very noticeable lumps, along the roots; and the better the crop the more nodules there are. Finally, scarcely a generation ago it was shown that these nodules are inhabited by colonies of bacteria, which make their way into the root in order to find the food they need. But they give the plant more than they receive. They have, it may be, the unique power, certainly the most wonderful power, of taking the nitrogen that is at large in the air and "fixing" it. This nitrogen is in this way directly fed to the plant, and accounts for its special greenness. A clover plant will, for this reason, stand out vividly green — always the sign of a nitrogen diet— on the brownest lawn. If a clover crop is ploughed in, all this nitrogen is added to the soil, but a great quantity is left. The earth is richer although it has spent riches. It has had mineral food extracted from it, but the stuff taken from the air by the bacteria and the plant more than make good this loss. The air, we may say, has made a present to the earth.

THE RESULT OF INFUSING BACTERIA INTO THE SOIL

A row of sweet peas fifteen feet high

EYES OF FIRE THAT PIERCE THE NIGHT



Life, which brings forth the beauty of a red rose and the music of the nightingale, brings forth, too, the terror of a roaring lion, prowling through the forest by night, as painted here by Mr. Briton Rivière, R.A.

RIVALS FOR THE MASTERY

The Early Days of the World when Man and the Mastodon Set Out Together

WHAT THE FIRST ANIMALS WERE LIKE

MAN is lord of the animal world, its highest consummation; but what if man had never been, if he had not emerged from the kaleidoscope of life? From what type of created things would Nature have then evolved the autocrat of the earth? How would she have fashioned him, how arrayed him? With what powers would she have invested him?

It is hard for the lay mind to conceive of a world without a man, though it was such a picture, indeed, that the earth presented until organic life had been millions of years established. We dimly realise that time and space have neither beginning nor end; and human life seems at first sight also to belong to the infinities. The idea of man's late beginning and his lowly origin seems too unreal, perhaps, for our acceptance. The picture of man as semi-human, a beast warring with other beasts for bare existence, comes to our minds as preposterous and grotesque.

But the fact remains that man is the parvenu of creation. He is the most modern of mammals, just as mammals, with birds, are the most modern members of the animal kingdom. We can trace life for millions of years before the emergence of the most primitive and fantastic mammal. The earth and its waters had been the home of a host of types of life before the faintest indication of a mammalian form first took shape. The chances against the success of the type were infinite. A little greater voracity, a little greater speed, or a little greater cunning on the part of some predatory reptile, and the form in which the rudiments of the mammal first found a home might have been utterly destroyed.

Had the vital link been snapped, had the ascending line, of which man is the summit and the glory, been severed, from what other type would Nature have fashioned her greatest son? She was ruthless but impartial. Every type had the same genesis. Everything living to-day derives from the lowly primordial organism with which life originated. The same elements differently combined in a speck of protoplasm, may produce a Shakespeare or a serpent. From a speck of life no more elaborate than that from which the first living creatures arose may spring a Hannibal, a Dante, a Napoleon; from the same sort of miraculous speck, differently made up, may proceed a reptile or a singing bird. The early embryonic stage of the greatest of mankind may be indistinguishable from that of the lowliest mammal or reptile. It is in the development that we read the marvellous story of some of the changes evolution has brought about.

Man, descended from a water-breathing creature, carries with him the evidence of his lowly life. A frog, after sacrificing gills, and its means of sucking, and its tail, and taking unto itself lungs, and jaws, and legs instead, famishes and dies if unable to escape from the water without which it would have perished a week or so before.

So packed with the effects of age-old evolution, so inexorable, is the operation of the law which, in the course of years past numbering, has brought the amphibian to his present development and needs. The foundation of life has not changed; the vital principle is unaffected, unmodified; the same primitive speck is the fount of every living creature. The embryo remains the epitome of the life-story of the species, and in its development we watch the almost incredible story unfolded, showing us by what strange steps Nature has brought all creatures to their present stage of perfection.

With this unswerving impartiality which has distinguished her, Nature gave all types of life a chance, and the sovereignty of the world was the guerdon to be gained.

It was a veritable kingdom of the humble at the outset, of mere moving particles of life, yet not to be despised, inasmuch as here was the first of all miracles, the creation of animate existence, of life in other than vegetable form, and highly to be reverenced, be it remembered, as the ancestral form of all subsequent organic life. The kingdom was owned by the protozoa, and between their appearance and the advent of the first of the vertebrates elapsed the longest of all the periods into which the history of the earth is divided.

Nature has quickened her methods since then. We need not attempt to catalogue the early stages of this story of organic life. The record is lamentably incomplete, though some of the early forms have left their record in the shape of cliffs and mountain ranges built up solely of their skeletons. Great cities flourish on foundations built up of the minute shells which sank in unnumbered millions to the bottom of oceans which have long since changed their beds. With the vertebrates came a scorpion, among the first of known land animals. It was a great day in the history of the world when he first crept out of the waters.

THE FIRST AVIATORS: THE REPTILE ANCESTORS OF THE BIRDS

Then our record takes a flying leap and clears millions of years at a bound, for among the next notable finds revealed to us is the ganoid fish. We have as yet no record of the intervening forms which must have led up to this specialised animal, but here the story of evolution is first graphically impressed. The great battle for existence, for betterment, for conquest, had begun. The making of man was still far off in the ages of Time; but the fight, beginning with the inception of life and continued ever since, was in full swing. The fishes had armed themselves; they had laid on plates of mail and cultivated formidable sharp-gripping teeth. "Eat or be eaten" was the law. And the scorpion, wearying of the conditions, had betaken himself with his sting to the land, though leaving his family abundantly represented in the waters.

In the same line of ascent with these creatures came the insects and spider-like animals. And here was another significant era in world-history. In the insects an order was here brought into existence destined to have immense influence upon practically every other form of life. Forth came parasites to prey upon other animal forms, to play their part in the vegetable world, and prepare a way for man. With the insects came a higher intelligence than had yet been created. Improvement was proceeding.

The coming of the insects at a time when the other life forms were seemingly so different from them has been a puzzle to many a student, but readers familiar with Lord Avebury's valuable studies find there a good anchorage. There seems at first to be little in common between the

stag-beetle, the dragon-fly, the moth, the bee, the ant, the gnat, the grasshopper, and other less familiar types, all differing in size, in form, in colour, in habits, and in modes of life. Yet the researches of entomologists have proved not only that such insects, while differing greatly in details, are constructed on a common plan, but also that other groups can be shown to be fundamentally similar. While the mature forms differ greatly, the embryo forms are so similar as to be clearly reducible to one common form.

Millions of years were passing, and new forms continued to appear. Special types arose and vanished, unable to tolerate the altered conditions which successive ages imposed. Bulk and strength were the dominant features of the newer developments. Crust-clad animals of colossal size arose, and subsided into the mud which has become rocks. Vast cuttlefish thronged the seas, and many a legion of molluscs. Then came the amphibians, water-born animals which go ashore to live, and the way was clear for the reptiles. At this point the race for the mastery of the world became a thing of stern reality. Not consciously, of course, but by their very existence the reptiles sought supremacy. And they obtained it. The world was at their mercy, and this fair earth had lizards and other reptilian monsters for its lords.

In the sea were the huge fish-lizards with paddles for limbs and bodies like whales, which brought forth their young alive. Sharing the shallower depths with them were giant amphibians, with limbs adapted for progress on the land. Some types of reptiles made their home permanently on land, browsing on the luxuriant vegetation which earth afforded; but they were themselves the prey of carnivorous species of their own order. The dinosaurs—the "terrible lizards"— were kings of the earth. Among them were the Atlantosaurus, 80 feet long and 30 feet high at the topmost point; the Brontosaurus, 60 feet long, and weighing twenty tons; the Ceratosaurus, smaller in build but larger of brain, and apparently of greater activity than some of its contemporaries. There was the Iguanodon, a beast 30 feet in length, whose habits of rising on its hind legs curiously foreshadowed the colossal mammal of a later epoch the Giant Sloth of Patagonia.

A SCIENTIFIC RECONSTRUCTION OF THE GREAT MONSTERS THAT ONCE ROAMED THE EARTH

These fearsome monsters lorded it over the land, with none even to challenge their supremacy. The carnivorous dinosaur might conquer and devour the herbivorous dinosaur or any other giant lizard not so well equipped for fighting as himself, and smaller fry would be snapped up. The domination of the reptiles was complete. But nothing came of the mightiest of this strange family. Their development lay along purely physical lines. They grew like moving mountains, with huge, unwieldy strength and blind ferocity, but they moved in a vicious circle.

There is a limit to dimensions. The elephant could attain no greater size than the largest of his species now living, unless he evolved a greater number of legs. Nothing further could be done in the way of bulk, and the dinosaurs missed their destiny. The upright gait which they were able to

assume gave them unbounded possibilities. Their forefeet had become virtually hands, and as supply has created demand, so to speak, in the development of species, this greater advantage should have been turned to account, had there been brain power enough to suggest increased use of the privilege. But the opportunity passed. The dinosaur had its chance, but it was as if some besotted giant were placed to-day to govern a people; rude strength and ignorance of fear were insufficient, and Nature, as if recognising that here was another of her great failures, turned to the encouragement of another reptile group, from which the first mammal was ultimately evolved. A primitive egg-laying creature was this first mammal which at last arrived; between it and present-day creation the two egg-laying mammals of Australasia, the duckbill and the spiny ant-eater, are the sole surviving links. The first mammal was a small carnivorous creature the size of an opossum, but there was magic in the new type. From this group arose in time the ancestors of the whale and all its family; the Polar bear and the Siberian tiger, the anthropoid ape of the steaming tropics, the camel of the arid desert, the mammoth and the mouse, and, at last, lord of them all, man himself.

THE GIGANTIC SHIP-LIZARD OF AGES PAST

THE SABRE-TOOTHED TIGER, WHICH THE EARLY MEN FOUGHT

At about the same period came the first birds, beginning as flying reptiles, with flesh-eating teeth, with leathery, featherless skin—a new marvel in the kaleidoscope.

Here again was an animal seeming to have destiny ready for its own moulding. It had assumed an upright position; the membrane of its wings left its forefeet free to act as hands. It had a dual method of progression; it had two implements with which to work. But it brought to its new condition the mind of the reptile; it sacrificed brain to feathers and beak; it merged its arms and wrists and fingers in its wings, and left the race to the mammal, then humbly moving about the earth.

Mammalian forms of life multiplied, the reptile form declined. Could some superhuman, whom we may imagine gazing at the nebula from which our globe evolved, have pictured the scene on earth at this time, he would have had little doubt as to which order would wrest the ultimate triumph. The time for great specialisation was drawing to an end. Fishes in bony armour gave place to more generalised, more agile, less heavily protected types. The reptiles, having failed to develop except in bulk, became exhausted. They could not adapt themselves to changing conditions, and, like many other groups since their day, they fell back in the race, leaving descendants, it is true, but none to remind us of their ancient size and might, save the crocodiles.

From one of these many groups of mammals Nature had selected a new type for experiment. She gave it warm blood, she decreed that it should not produce young like those of the reptiles, ready to do battle at birth with the rest of creation, but young which should be nurtured by the mother. Affection came into the world when the first mammalian mother suckled her offspring, and with affection came the

characteristics which affection suggests—care, solicitude, pity, self-sacrifice. To be enabled to exercise these, an animal must develop its brain, and it is easy to imagine that, in the midst of animals so different from itself, the first mammals must early have risen superior to their contemporaries. They could not otherwise have survived.

But intelligence was still at a premium. The prize was not to be awarded for many an age. Mammals gradually followed in the track the reptiles had pursued to their own undoing. Size, strength, power of resistance to attack, adequacy of battling weapons—these were the determining factors. From lowly forms came forms more highly organised, and type after type grew to monstrous size. The whales, which were originally land animals, found the contest too severe, and retired to the greater freedom and lessened responsibility of life in the ocean depths.

A saguinary, hideous era followed while the struggle for supremacy was renewed. Strange giant beasts roamed the earth, more fantastic than any pictured by the mind of man. While land connections still remained between the continents, huge monsters developed and roamed from land to land, but climatic changes brought destruction to whole species. The animals that survive are infinitely fewer than those that have been blotted out of the book of life.

THE LORD OF LIFE

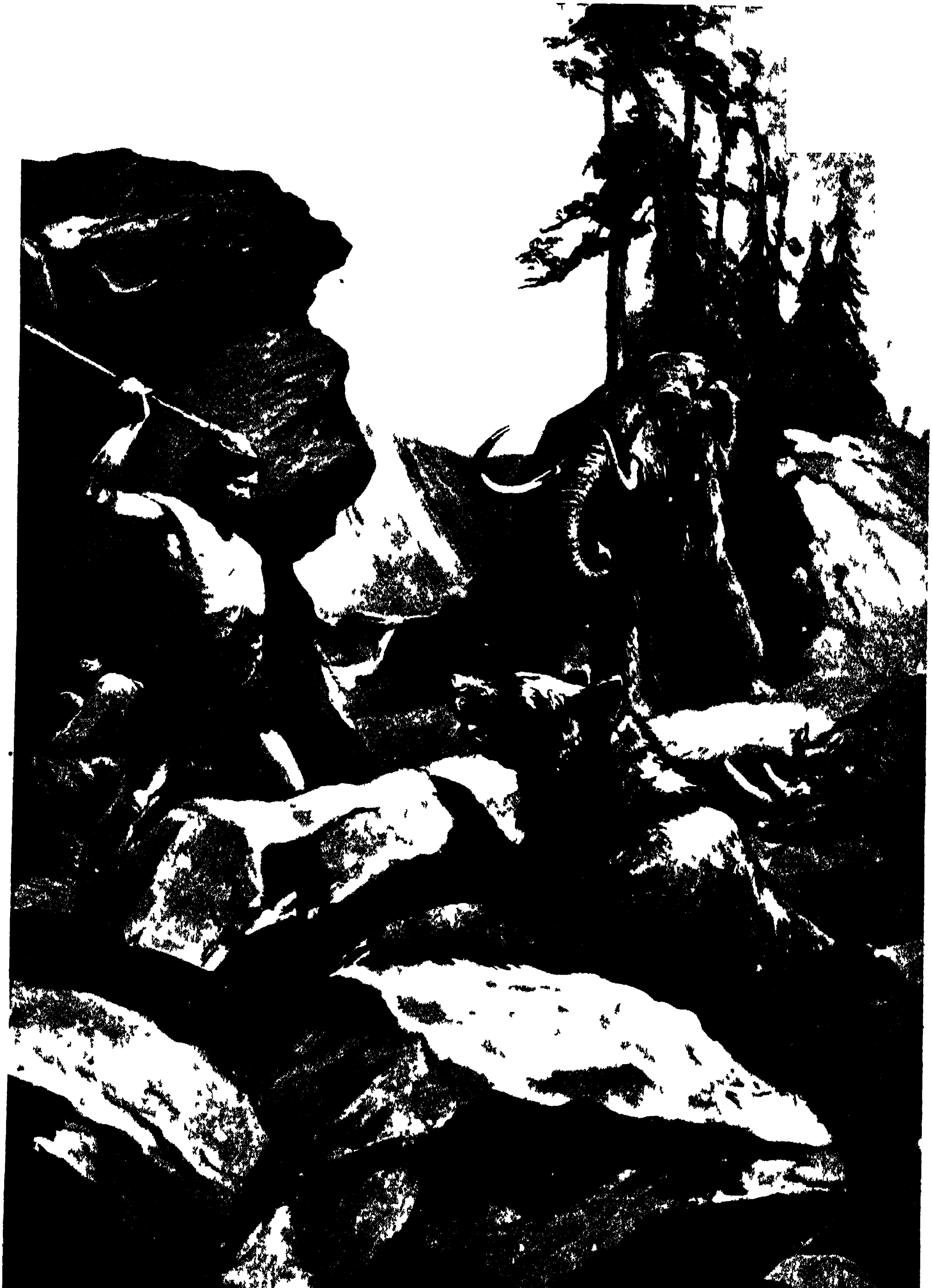
The huge carnivores, the sabre-toothed tiger, the great cave bear, and other bloodthirsty beasts, must at one time have seemed to have the race to themselves. But again brute power ran its fruitless course; the race was not to these, and their day passed. The reptiles had failed, the birds had failed, the great monsters had failed. There must be a new type, unless insects were to carry the prize. It is striking to remember that possibilities in the race for mastery lay with certain of the insects. The ants and bees had in them the power of organisation and governance necessary as a step towards dominion. That an insect could now alter its structure and characteristics to become a mammal nobody would dream of asserting, though Agassiz laid it down that the possibilities of existence run so deeply into the extravagant that there is scarcely any conception too extraordinary for Nature to achieve. But insects appeared æons ago, before the lancelets and the true fishes, the snakes, the lizards, and the birds; there was time for them to have developed along higher lines.

Nature seems, however, to have been satisfied with them, and we must suppose that to a certain extent they have "marked time." Yet they have in some cases brought social life to a higher pitch of perfection than can anywhere else be found beyond the pale of human society. The ant, in point of instinct, ranks above all the mammals save man himself. It gave the world the first and highest example of civic life.

No animal devoting itself only to bodily development, to the upbuilding of bone and flesh and armour, could hope permanently to hold a lead in the race. Such an animal takes no thought for the morrow. The squirrel and the marmot, and other animals which lay by store for the winter, are ahead of animals ranking far higher in the estimation of man. Dogs and wolves, which hunt in company, are an advance upon the solitary animal.

But nowhere do we find the ability to rule, to control circumstances, to master environment so well developed as in the ant. It collects its seed, and in due season reaps its harvest. It impresses other animals for service—makes slaves, and—as was sometimes the case in ancient human society—comes in the end to be ruled by them. It keeps cattle, it rules a well-ordered city with admirable discipline, even to the extent of driving out the idle. Had the ants combined their balance of

MAN AND HIS NEIGHBOURS LONG AGO



The race for the mastery of the world became a thing of stern reality when man came to share the earth with the great monsters This little man according to all the laws of chance, should have been gobbled up by a tiger or crushed by a mastodon, and have disappeared for ever off the earth

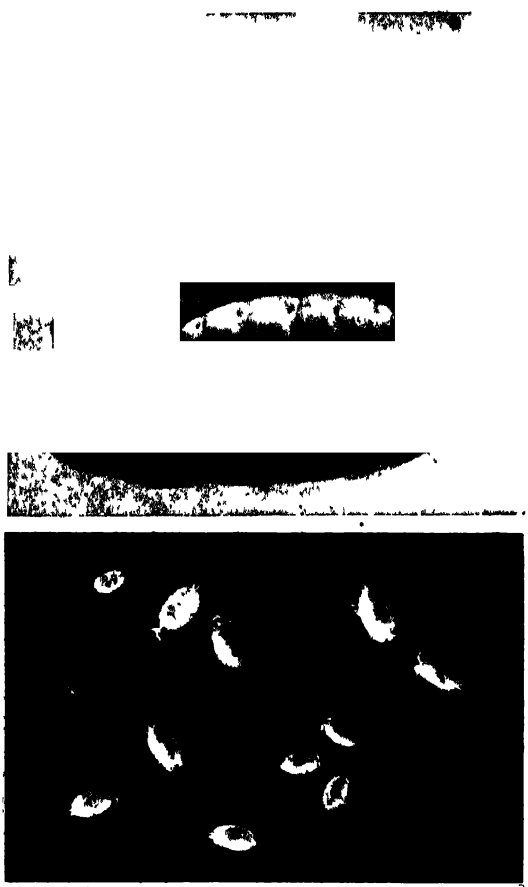
MAN AND HIS NEIGHBOURS TO-DAY

But man beat the mastodon. With strength almost unimaginable, with cunning such as man can barely foresee, with endurance unsurpassed in any human being, the forerunners of man succumbed to the only animal that can throw a stone. In the animal kingdom man has put all things under his feet.

experience and specialised instinct with greater bodily development, involving greater responsibilities and greater opportunities, they might in course of time have stood forth as decidedly competitors for the higher honours of the race.

But the pageant of life passed on still without a leader definitely chosen. The mammalian brain began to develop apace, and physical bulk became of smaller account. The whale survived because its medium was favourable, and its enemies inconsiderable. The elephant, rhinoceros, and the hippopotamus persisted, and they still linger with us. The elephant comes of a form of life which was at one time in the forefront of the contest. Like the rest of the giants, he developed from small beginnings, but, unlike the majority of them, he developed brain with brawn and bone. The mental faculties of the elephant have shown a gradual development throughout the ages; and if the elephant could breed in captivity, as our domestic animals do, we should probably have to place him first among intelligent quadrupeds. But every domesticated elephant begins at the bottom in the task of educating himself in association with man. He must be caught wild, and has no opportunity of handing on his experience to his kind, as do, for instance, the horse and the dog.

And so, inevitably, the mastery of the earth lay waiting for the group from which man was evolved. The task of subjugating the rest of the animal world had to lie with an animal which could carry itself upon its hind legs, leaving the forelimbs free to use weapons and tools. There is no other tool-wielding animal but man. The ants and bees and wasps, the beavers and some of the smaller animals and birds, are wonderful engineers, having mastered problems which man solved through many weary ages. But though the homes not made with hands are wonderful and highly to be admired, there is no hope in them. The reptiles lost their chance when, able to erect themselves, they made no better use of their forelimbs than the kangaroo makes to-day. The birds muffled their hands in membranes and feathers; the bats chose wings in place of hands; the giant sloth, which pulled down tree-tops with his forelimbs as he squatted upon his mighty haunches, had not brain enough to go a step further and keep himself alive. Certain rodents are among the types which have retained some power of the hand in their forepaws, and birds of the parrot tribe extract similar service from their claws. The elephant has a wonderful implement of prehension in his trunk, but he would require two trunks to wield a tool.



COULD THE ANT HAVE RULED THE WORLD?

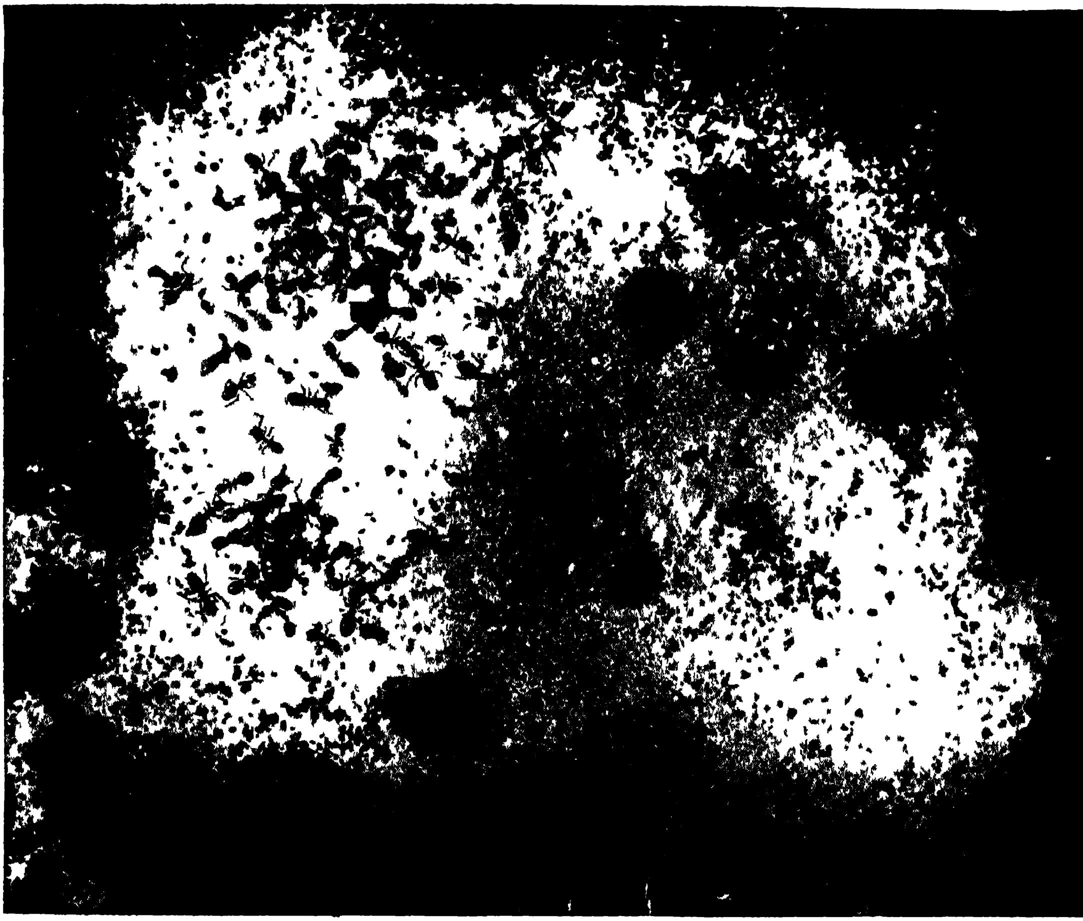
Lord Avebury has suggested that in the absence of man th ant might have become master of the earth. Nowhere do we nd the ability to rule so well developed as in these remarkable insects, which enslave other insects—the aphids, sho the lower pict into their service. The whit or termites display an even higher intelligence when the eggs are about to b laid by the queen, hiding away the mother for a period, as sho the top picture, where the royal prison- cut in two.

The primates had to come, and an aberrant type to bring forth man. "Structure for structure," says Huxley, in a well-known passage, "down to the minutest microscopical details, the eye, the ear, the olfactory organs, the nerves, the spinal cord, the brain of an ape or of a dog, correspond with the same organs in the human subject. Cut a nerve, and the evidence of paralysis, or of insensibility, is the same in the two cases; apply pressure to the brain, or administer a narcotic, and the signs of intelligence disappear in the one as in the other. Whatever reason we have for believing that the changes which take place in the normal cerebral substance of man give rise to states of consciousness, the same reason exists for the belief that the modes of motion

of the cerebral substance of an ape, or of a dog, produce like effects."

So that man, let us say, was inevitable in the scheme of things. We know nothing of the language of animals, though we realise that they have some mysterious method of communication. Man is the only animal with ordered oral speech. Without him there would be no language, no music save that of the birds. There would be no building on earth more ambitious than the earthen city of the ants, the dam of the beaver, the hive of the bee, the subterranean colony of the rodent. Man, emerging from his fetid cave, and abandoning his kitchen midden, has steadily ascended in the scale of life. He has defied the laws of Nature, for when conditions which should have killed him have come, he has adapted himself or risen superior to them. He has bent natural laws to his purpose. Nature has hounded to death far more types of life than now exist upon the earth. She has heaped scourges upon man himself, but man has wrung from her many of her subtlest secrets, and he looks hopefully forward to a future when he shall have conquered them all and become indeed the master of the earth.

There were sovereigns of this earth before man lived, but they were unconscious both of their sovereignty and of the possibility of self improvement in point of the only quality that counts—brain. Man alone has developed the masterful brain which wins lordship over the earth and all that is in it. The struggle has been fierce and prolonged, but the victory is inestimable. Meanwhile the animal nearest akin to man in the lower scale from which he sprang jibbers still among the trees, affectionate to its kind, compassionate, faithful unto death; dreadfully human in some aspects, dreadfully brutish in more; as inferior to the lowest savage as that savage is inferior to Shakespeare.



THE HOME OF THE ANTS, WHICH MIGHT HAVE WON THE RACE FOR MASTERY IF MAN HAD NOT BEEN

Had the ant combined its balance of experience and specialised instinct with greater bodily development, involving greater responsibilities and opportunities, it might in time have stood forth as certainly a competitor for the mastery of the earth. [Photo by Rev. S. N. Sedgwick

NATURE REVEALS HERSELF—YIELDING THE TREASURES OF EARTH TO HER INSURGENT SON

Man is making the world anew. For perhaps a million years and more he has struggled in ignorant misery with natural conditions, but at last Nature is revealing to him her secrets, as Mr. Abbey pictured in this fine painting. With this new knowledge of Nature, man is unlocking the gate to a larger and happier existence.

THE MASTER OF THE EARTH

The Difference that makes the Difference in Man—How he Set Free his Hands and became Lord of Creation

THE MOST ASTONISHING THING IN NATURE

"What is man, that Thou art mindful of him? Thou hast made him a little lower than the angels, and hast crowned him with glory and honour. Thou madest him to have dominion over the works of Thy hands; Thou hast put all things under his feet: all sheep and oxen, yea, and the beasts of the field, the fowl of the air, and the fish of the sea, and whatsoever passeth through the paths of the seas."

WHAT is man? remains the question of questions now, as it was more than two thousand or ten thousand years ago. The "lord of creation," on whose dead body the worms feast, the paragon and paradox of animals, asks what he is, and whence and whither and why.

But in our own time the question is nearer answering than ever before. The nineteenth century established a staggering yet evident truth, which not even the ignorant now challenge, and the twentieth may establish truths regarding man's mind no less notable than the Darwinian demonstration of his bodily origin.

In this opening chapter of the study of man it is open to us to adopt either of the two tendencies which for half a century have divided the students of this subject. They are well defined, and there is no mistaking to which party almost any writer belongs. We may insist upon the numerous radical, profound, unchallengeable, all-significant resemblances between man and the lower animals, and may demonstrate beyond question that he is their relative, that the fundamentals of his constitution are the same as theirs, that his body has the same needs and the same destiny, that his young pass through similar stages, and even that, at certain stages, they are actually indistinguishable from the young of his nearest animal allies.

Meanwhile, we may slur over or minimise any differences as non-essential, superficial, trivial. It is true that, by this method, we shall succeed in leaving man wholly unexplained as regards his record and his place in Nature, but if our object is to show that he is only the most modern of the apes after all, we shall be content.

On the other hand, we may prefer to insist upon the numerous radical, profound, unchallengeable, all-significant differences between man and the lower animals, and may readily convince ourselves, by this means, that he is unique, unprecedented, unrelated, incomparable, an exception to all laws. It is true that this method also has its disadvantages, since it leaves wholly unexplained the origin of man, not to mention half his attributes of mind and nearly all his attributes of body. But as our object in this case will be to disclaim any connection with our poor relations, we shall waste no more regrets upon the distortion of the truth than if we were snobs of any other kind.

Science, however, so long as it is true to itself, must ignore or despise no order of facts. Its object is truth, of which all facts are part. If the body of man displays some hundreds of definite anatomical characters which it shares with the anthropoid or man-like apes, and with no other living beings, science must reckon with the fact and its meaning. If the mind of man displays powers so far transcending the utmost displayed by any other form of living Nature that we are almost entitled to call him supernatural, if his genius in a hundred directions is as unimaginably novel as his backbone or his muscles are archaic, science must reckon with this fact, too. If there is apparent contradiction, it must be faced, with the full assurance that it is only apparent, and that truth lies in the explanation, whatever it be.

Here, then, we take no side. Disraeli's contribution to the mighty controversy of last century was to declare that, if asked

whether man is "an ape or an angel," he was "on the side of the angels." Science cannot afford either to take sides or to satisfy itself with smart antitheses. Man is neither an ape nor an angel, because he is clearly both; and if we are ever to understand him—which means understanding ourselves—we must pay equal attention to "the base degrees by which he did ascend," and to the noble reason, the infinite faculties, the apprehension "how like a god," which his greatest poet perceived in "this quintessence of dust." We are for all the facts. If man is a part of living Nature, and was so evolved, we are for that; if he transcends incalculably all other living things, we are for that also.

The Mark of Man and his Cousins in the Animal Kingdom

Plainly, our first concern is to observe and define those characters by which we may identify the human species. This is no more for the purpose of exalting or depreciating man than if we were seeking to define and distinguish the horse and the zebra, or the oak and the elm. Man forms a species of the animal kingdom, and his specific characters must accordingly be defined. He is evidently a vertebrate—as evidently as the herring, the frog, the lizard, the lark, or the lion. He is no less evidently a mammal—a member of the great mammalian order, whose mothers suckle their young; and there can be no question as to the particular kinds of mammalia to which he is most closely allied. He is far from the whales and the rabbits and the bears and the cats. His allies are the lemurs and monkeys and apes, especially the apes. In all the world, four species of apes, called man-like, come nearest to him—the gibbon, the orang, the gorilla, and the chimpanzee. He and these may be ranked as Primates, or first—being also last, but "the last shall be first"—among mammals. And when his cousinships have thus been established, we must observe the characters by which his species may be distinguished even from those which most closely approach it.

The Things that Belong to Man Alone, by Virtue of Which He is Man

There is, of course, a multitude of differences which are distinctive and might be described at any length. Man's hand and foot are his, and not another's. Man has acquired a chin, has lost nearly all his hair, and so forth. Our immediate concern, however, is with greater things, much less obvious, it may be, but greater, because *they make the difference.* Man is not man because of his chin, nor because of his denuded skin, nor the angle of his jaw. These, and a hundred other peculiarities, are very interesting and notable, no doubt, but our first concern must be with what makes man man. He can think and reason, and speak and write, and imagine. In part the creature of environment, like all other living beings he can also create environment according to the pattern of his fancy, can "shatter it to bits and then remould it nearer to the heart's desire." His chin, his skin, his heels will not explain these deeds, and we want the facts which do.

Let us observe, then, first, that man the erect is also "man the erected," as Robert Louis Stevenson calls him. His cousins use all four limbs for the same purposes; they are both four-footed and four-handed—so far as they go. It is true that, in some degree, they foreshadow what is to come. They are not erect, but at times they are semi-erect. The gibbons spend much of their time erect, but that is because they hang vertically by their hands.

The Change in the Mechanism of a Man by which He is Erected

The gorilla may support itself by a stick, and so approach the "upright posture" or "erect attitude," which all anatomists agree in stating as the first distinctive characteristic of man. But the erect attitude can only be temporarily assumed by any ape. The mechanics of its body are against it from the first, just as they are against it in the body of the young baby.

The posture of the body really depends upon the position of the hip-joints. If we examine the body of any ape, or of a baby, we find that a line, dropped to the ground from the "centre of gravity" of the body, passes in front of the hip-joints. The upper part of the body, therefore, necessarily tends to fall forward until it is supported by the fore-limbs or arms.

The simple concave-forward curve of a baby's spine condemns it to a four-footed stage. The bodily centre of gravity is situated in front of the hip-joints, and the baby's inability to walk depends thereon, and not merely upon lack of practice or upon muscular weakness. But in the course of its development the curvature of the baby's spine undergoes a change which "recapitulates the history of the race." The consequence of this change is to throw the centre of gravity of the body behind the hip-joints, so that

the erect attitude is not only natural, but inevitable, and the constant tendency of the whole of the body above those joints is to roll, not forwards as in all other mammals, but backwards. There has accordingly been developed, upon the front aspect of each hip-joint, a band of tissue, the largest and strongest of its kind in the body, which prevents the body from rolling backwards, and which, of course, is not to be found in apes or monkeys, who have no need for it.

Man has thus been erected. The backbone, which began horizontal in the first fishes, is vertical in him, and this change of axis means almost more than words can say. It is true that, in a sense, the birds are erected also. Their fore-limbs have, indeed, been raised from the ground, but they have not been freed from the purpose of locomotion. On the contrary, they have been more exclusively confined to that purpose, and specialised for it. For its pains the bird has gained the power of flight, but it has lost any chance of ever making a flying-machine, or playing the piano, or writing a book. The bird's wing is marvellous in its way, but it is nothing compared with the hand of man.

THE BAND OF MUSCLE WHICH KEEPS US UPRIGHT

The erect attitude of man is unique, and necessary to his uniqueness, in that it involves the complete liberation of his fore-limbs from the purpose of locomotion. The alteration in the poise of his body is such that he can walk upon his feet alone, and finds that he has his hands free to play with and to work with.

Fortunately they are complete. The original vertebrate limb, as we see it represented in the frog, terminates in five digits. In subsequent forms of life some or all of these digits have frequently been lost—as in the whale, the pig, the horse, and even the bird, which has only three and a half fingers in its wings instead of five. In the human line, however, no digits have been lost; and when man's fore-limbs were enabled to leave the ground in the erect attitude they were provided with their complement of digits, once toes, now fingers and thumb, to whose possibilities as servants, and even as tutors, of his brain no limits can be set.

This is the real meaning of the erect attitude as the dominant physical characteristic of man. By the assumption of that attitude he has lost in speed, and is not the climber that his ancestors were. His body is by no means perfectly adapted to it. The valves in the veins of his limbs, for instance, are arranged for the due control of a flow of blood as in a horizontal animal, and are by no means so placed as to suit him best; varicose veins are often the price he pays for this innovation. Far more hardly does the assumption of the erect attitude bear upon women. It is, indeed, the permanent underlying cause of the extraordinary contrast between human childbirth and its parallel in the case of the lower animals. The modern anatomist finds himself able, therefore, to translate the story of Genesis into his own language. The curse of Eve, "in sorrow shalt thou bring forth," passed upon her as the price of the knowledge of good and evil, is veritably the price which the Eves of the race pay to-day for the assumption of the erect attitude, and for the knowledge of good and evil which that attitude has greatly helped man to gain.

The erect attitude raises man's physical stature, of course, and in any case he is a giant compared with his nearest relatives. The pose of his head, upon his erect spine, further assists him in his survey of the world. His horizon is vastly extended. He gains also in dignity and in all that appearances count for in his control of the lower animals. But when all this is said and allowed for, the fact remains that the attitude in itself is of no moment compared with its all - important consequence — the liberation of his hands.

From this moment onwards, man's hands and his brain act and re-act on each other. Like the apes, man is naturally curious and imitative, as we recognise when we speak of "the pride that apes humility," and his hands serve him at every turn in the satisfaction of his mental tendencies. They are in themselves endowed merely with the senses of pressure, heat, cold, and pain, which are found in the skin at large. But the form of the hands, their power of grasping, the independent mobility of the fingers, together with their naturally rich endowment of nerves, practically supply him with a new sense, as valuable, as educative, well-nigh as distinctive as vision or hearing. He can now study the surfaces, the textures, the consistence, the forms of all manner of objects as never before; and the very instruments of his senses are also, by perfect adaptation, the most

admirable and versatile instruments of his will. We who are now adult forget, and can only remind ourselves by watching babies and young children, how valuable our hands were, as means of instruction. The baby handles everything, and commonly carries what it can grasp to its lips, which are even more richly endowed with nerves than are the fingers themselves. Children need constantly to be told not to touch, their natural instinct being to handle and to finger everything, for the sake of knowledge and the power which knowledge bestows. Consider, then, the horse, for instance, who has only two digits in all—one remaining in each fore-limb—to correspond to our hands, and who must use these constantly for locomotion. Since the basis and beginning of all knowledge is sensation—the senses being, as Bunyan called them, the gates of Mansoul—what chance has the horse or the bird or any other creature against man, the only or unique owner of two free and perfect hands?

THE BABY HANDLES EVERYTHING
The child's habit of grasping whatever comes within its reach is striking proof of the value of the hand as a factor in education

In the nineteenth century, when the great fact of man's descent was first recognised, and when notions of heredity, such as we must now reject, were unquestioned, this great argument about man's hands and the erect attitude was further extended. It was supposed, not merely that the hands taught the brain of the individual, but that thereby the native characters of the brain of the race were enhanced; the brain of the child whose father had thus been taught would be naturally the better therefor, and thus, by steady accumulation, we might account for the modern capacities of man's brain, as really, in a sense, the creature of his hands.

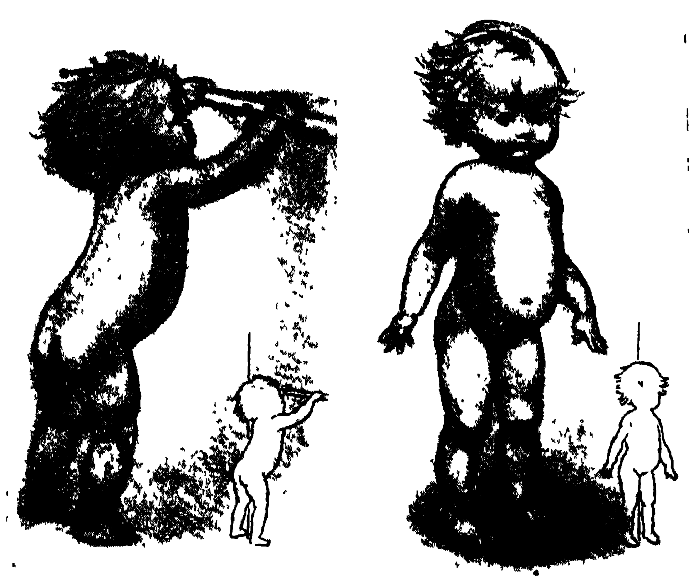
THE FIRST METHOD OF HUMAN PROGRESSION
The curve of a baby's spine condemns it to a four-footed state of existence in its infancy

This view must now be rejected. The evidence is clear that the brain is the beginner and the beginning. A creature that possessed a less than human brain, but was endowed with human hands, would be far from human, just in proportion to the inferiority of its brain, its hands notwithstanding. We might as well suppose—as many people do, or think they do—that it is the hands that make the mighty surgeon, or pianist, or painter, whereas it is the brain in each and every case. Further, we are clearly satisfied that, notwithstanding popular opinion, the education of the parent's brain is of no consequence to the child's; "acquired characters," or, rather, the effects of use, are not inherited. Whatever, therefore, be the history of the human brain, and however justly we rate the value of man's hand as its servant and instrument of instruction in the individual, we must reject the view that the hand has made the brain in the history of the race. The erect attitude is very important, and man would be somewhat less than man without it, but it cannot claim to have made man man. More probable, indeed, would be the supposition that the human brain had made the erect attitude possible by its influence upon the structure and balance of the body.

Here, and here only, notwithstanding all else that anatomists may describe, can we discern the differentia, the difference that makes the difference, of man. Man is man not because he has a chin or walks erect, but because he possesses the brain of man. Here we discover new structures, characteristically and exclusively human, in a degree which is true of no other structure or function of his body. Man's bones and muscles, his teeth and stomach, his liver and lungs, his heart and his jaws, contain and display differences as those of any species do, compared with any other, but they do not display absolute novelties, nor anything approaching them. Indeed, so far as the rest of man's body is concerned, we find that his differences, such

as they are, belong to the class of defect rather than excess, minus rather than plus, subtraction rather than addition. This, that, and the other structure he has lost, or possesses in a diminished form, such as hair and claws, much of the digestive tract, and many muscular and bony items. If we are to find, anywhere in his body, the key to his status, any physical structure to correspond to his psychical superiority, we must turn in some direction where we can discover not a mere shedding but a positive addition.

It is, of course, in his nervous system that we shall be rewarded. Not in the spinal cord, which is almost just such another as a host of his ancestors and cousins possess; not in the lower portions of his brain, which control the breathing and the beating of the heart, and the processes of digestion; not even in the middle levels of his brain, which are concerned with such functions as vision and balance. Not yet do we find anything new, nor, indeed, do we always find that man is here the equal of his inferiors. The process of subtraction, which we notice in his skin, may be observed also in, for instance, that portion of his brain which is devoted to smell—a definitely atrophied sense in man.



THE CHANGE WHICH ENABLES A BABY TO STAND

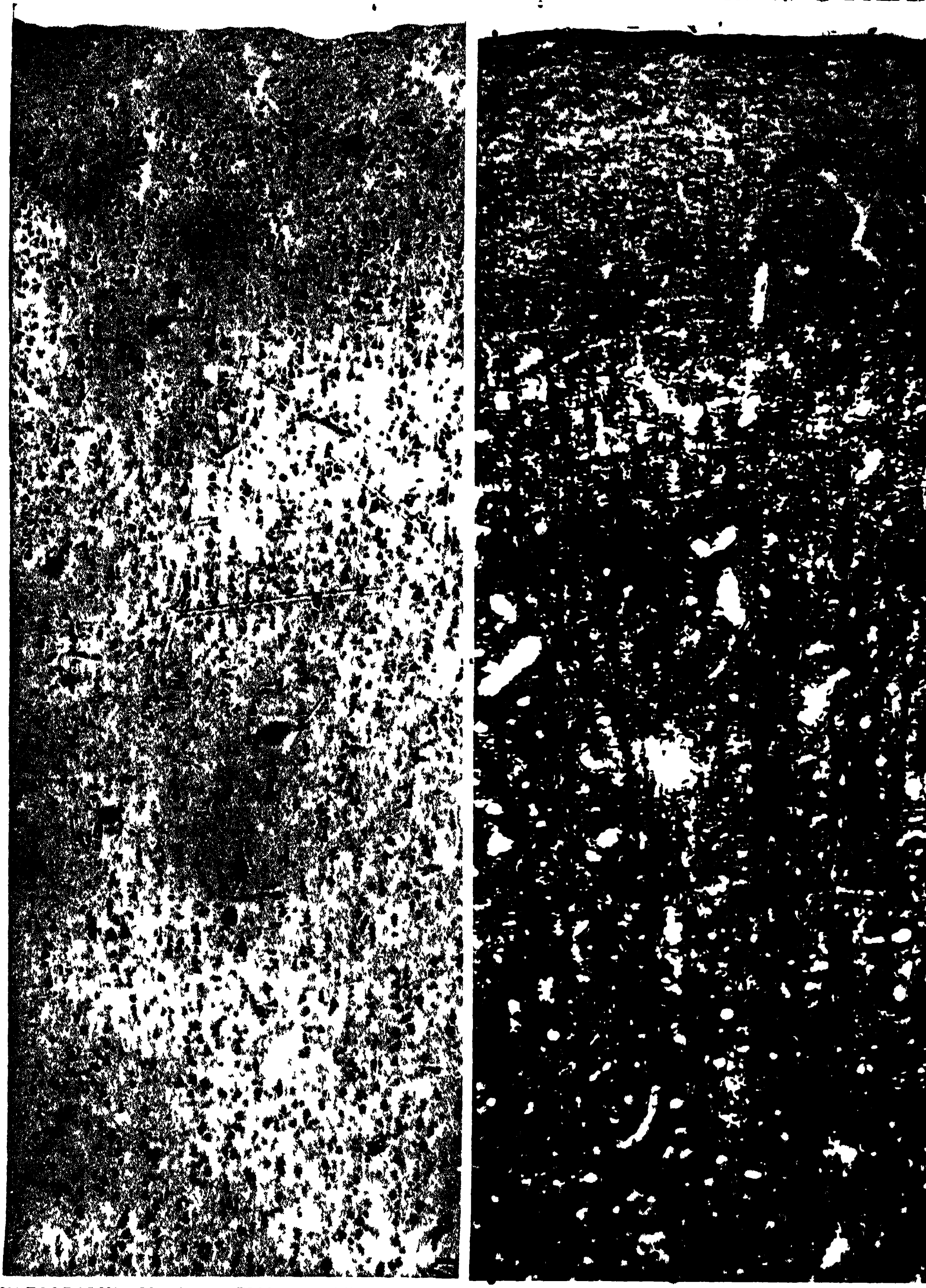
Man has overcome the four-footed state of existence for which his body was clearly made. A baby cannot stand because at birth the bodily centre of gravity is in front of the hip-joints, but a change takes place early which throws the centre of gravity behind the hip-joints, and the largest band of tissue in the body prevents the body from falling backwards.

Not until we reach the highest thing in man do we reach the new. When we have reached beyond the levels of sense and balance, we come to a mighty fold or mantle of brain tissue which, being comparatively new, is called the neo-pallium, or new mantle. It is so large in man, so abundant in structures which he alone possesses, that it requires to be folded over all the rest of the brain, which, indeed, it entirely obscures from view. Room for it can only be found, even so, by a process of surface folding, so that it is thrown into a number of "convolutions," with intervening folds. Its size, in proportion to the size of man's body, is enormous and unparalleled. Evidently here is something new.

Not, however, until we bring the microscope to bear do we discover what this evident novelty really means. It is covered with a thick layer or bark—as its Latin name, the cortex, means—of grey matter, much thicker in man than in any other creature, and of far greater extent, since it dips into all the many folds upon the surface of his "new mantle." Examined under the microscope, this grey layer is found to consist of millions of nerve cells, of which the greater number, and the greater number of types, are new in man. Without them one may be an idiot or an imbecile, having the human form in some degree; but they are necessary for man, since they are the appointed habitation of the human spirit. To the study of this incomparable structure we shall, of course, return. Our present business, in discussing the question "What is Man?" is merely to note that in so far as he can be said to be anything material at all, he is his grey matter.

This is the plus of man, "the little more and how much it is," the difference that makes the difference. It is the stuff that weighs, and yet may sway the sun, in virtue of which he has "put all things under his feet"; and if Carlyle was right in calling genius "the clearer presence of God Most High in a man," then the grey matter is the very holy of holies, the most tangible and essential incarnation of the Creator in the highest type of His creatures. It is here that life becomes most intense, most original, most creative, most unprecedented, most unpredictable, most infinite.

THE GREATEST MARVEL OF THE WORLD

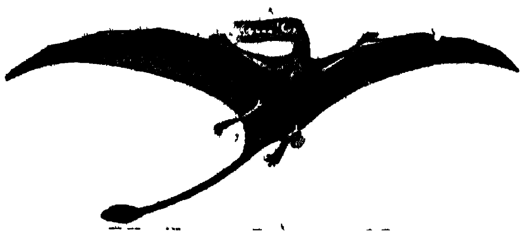


PHOTOGRAPHS OF A SECTION OF THE BRAIN MUCH MAGNIFIED, SHOWING THE FIBRES AND

The photographs on these pages are three of the most remarkable pictures upon which the eye can gaze. They are among the very best pictures ever taken of the human brain, and have been specially taken for this work by Dr. F. W. Mott, F.R.S., chief pathologist to the London County Asylums. On the left is a section through the grey matter, showing typical cells—of which there are perhaps 3000 millions—and on the right of this page are the fibres connecting the cells. As no process of staining sections is yet known which shows cells and fibres perfectly at once, it is necessary to give separate pictures. The first is of a section 1-5000th of an inch thick, and shows five layers of cells of different structure (marked on left). At the top are the molecular cells, and below are three layers of cells of pyramidal

A CENTRE OF ACTION IN A MAN'S BRAIN

THE CELLS THEY CONNECT, OF WHICH THERE ARE PROBABLY THREE THOUSAND MILLIONS
hape, with the giant cells—the seat of the voluntary impulses controlling muscular action—in the deepest layer. In the fifth layer the cells
re irregular in form. The large photograph is a giant cell, magnified 1650 times. A centre of nerve impulses which control the "doing"
f things, it is called a psycho-motor cell, because it is not merely motor but voluntary-motor, controlling the action of the muscles of
he body. Most of the cells and fibres are, however, concerned in receiving impressions, elaborating them by association, and storing
hem up in the memory. It is through these cells and fibres that we are conscious of our relations to the world around us, and we know
hat they are the anatomical basis of mind, because they are ill developed in imbeciles and wasted in those who have lost their mind,



THE HANDS OF A FLYING REPTILE
Showing how the little finger has developed

THE HANDS OF THE MODERN BAT
Showing the projection of the thumb

And now it is possible to make an admission which the physical study of man forces upon us. Not only is he *not* "the paragon of animals," if he be thus studied, but he is far from it. All who have thought upon this subject have perceived the paradoxical contrast between man's supremacy in the world and his physical inferiority, for inferiority it certainly is; and all have the more abundantly insisted upon the importance of man's mind, to which his bodily degeneracy lends such point. Said Sophocles: "Many are the mighty things, but none is mightier than man. He conquers *by his devices* the tenant of the the fields." Again, consider the famous saying of Pascal: "Man is only a reed, the feeblest in Nature, but it is a reed that thinks." Other authors have been struck by the feebleness of man's body. Shakespeare makes Lear, watching a naked man, say: "Is man no more than this? Consider him well: Thou owest the worm no silk, the beast no hide, the sheep no wool, the cat no perfume . . . Thou art the thing itself: unaccommodated man is no more but such a poor, bare, forked animal as thou art." Similarly, Herbert Spencer tells us how he and Huxley, watching some boys bathing at St. Andrews, "marvelled over the fact, seeming especially strange when they are no longer disguised by clothes, that human beings should dominate over all other creatures, and play the wonderful part they do on the earth." Carlyle's famous book on clothes, and the universal practice of savage and civilised man, show how man is really aware of the inadequacy of his "unaccommodated" body to justify his spiritual pretensions.

THE HAND OF MAN COMPARED WITH THE HAND OF HIS COUSINS, THE MONKEYS AND APES

On anatomical analysis the case against this "poor, bare, forked animal" is clear.

Man is, at birth, the most helpless of all living things, and this helplessness is maintained for an unheard-of period. At his best, so far as defence is concerned, he has neither fur nor feathers nor scales, but is the most

A BIRD'S HAND AND ARM
Showing how the feathers of the wing are fixed

HOW THE HORSE HAS LOST ITS "FINGERS"
Showing the evolution of its hoof

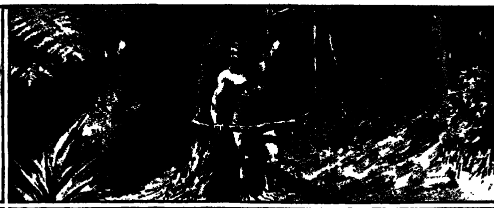
THE RISE OF MAN AND HIS CONQUEST OF NATURAL FORCES

THE STEPS OF POWER

Man Comes Down from the Tree

A JAVA FOREST SCENE

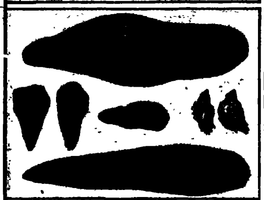
Showing man's first weapon—the branch of a tree—and the oldest human skull in the world, found in Java (upper), and a modern skull for comparison (lower).



Man Discovers the Use of Stone

THE OLDEST STONE AGE

Man picks up a stone and shapes it into a weapon; with examples of the oldest known stone weapons (size from 5 to 25 inches) and flint implements.



Man Finds a Home and Makes a Fire

SCENE IN THE CAVE DAYS

With a photograph of an actual section of cave-earth, in which were found flints and charred bones, and a needle, indicating the beginning of domestic industry.

Man Becomes a Craftsman

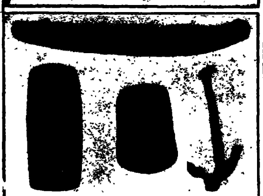
SCENE IN NEW STONE AGE

With examples of a bone harpoon and improved flint arrow and lance heads found in Ireland; and specimens of pottery showing development of home life.

Man Begins to Travel

THE BEGINNING OF SHIPS

Showing also the use of bow and arrow: with smooth hammer-heads, the anchor, and a dug-out canoe hollowed from a single trunk, the far-off parent of the Lusitania.



The Dawn of Agriculture

MAN BUILDS HIS HOME ON THE LAKES

With implements found on the site of Swiss lake dwellings, including stone knife in handle, and hatchets of wood, horn, and stone.

The First Village Communities

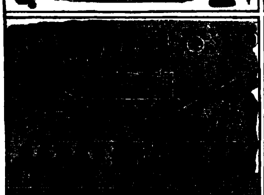
THE DIM BEGINNINGS OF COMMERCE

Man goes to sea, and makes a wheel, and uses anvils, bronze swords, and chisels, in his hut village. View of primitive ruins from Chysauster, Cornwall.

The Scientific Man

THE DISCOVERY OF THE LEVER

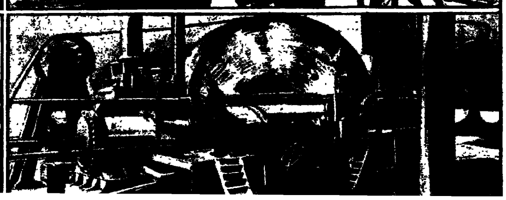
With examples of the mighty buildings of the ancient world; an Assyrian carving showing slaves moving a colossal statue of a sacred bull; and the great lighthouse of Alexandria.



The Dawn of the Modern World

THE AGE OF MACHINERY

Man discovers the power of gas and invents the steam engine, making a locomotive which carries him over the world; and civilisa-



THE TRIUMPH OF MAN

It may be a million years since a semi-human creature left the shelter of the forest trees, in which its ancestors had lived with the ancestors of the chimpanzee.

Solitary, weaponless — save for some broken bough—lacking the strength of the beasts about him, he was a prey to feelings of terror. His fears, however, increased his cunning.

Through his wants and shifts and pains, his intellect developed, and at last—possibly in Europe—he made his first invention, the rough stone tool.

By this time man had changed from a fruit-eater into an eater of flesh. Instead of gorging in autumn and starving in spring, he found food all the seasons. It was a great advance. He was a hunter and trapper. It was long before he found how to make fire, but he knew its uses. From a forest burning in summer, or from the lightning, he took the sacred flame that defended him from stronger animals, and enabled him to make sharp, hard, wooden spears. He improved, in the meantime, his flint tools, and he ended by making a huge stone with a point. Balanced on a branch just above the path of a mammoth, and tied with a creeper that easily broke, the stone brought down the great king of beasts.

It was now growing cold in the North, and the icefields were extending from the Pole. Man could no longer camp out comfortably by the river, and the caves were occupied by mighty creatures. But man had fire, and perhaps heavy stone clubs which broke through the thickest skull. Hand to hand, he seems to have fought the beasts, and became lord of the caves. He had found a home.

He invented the barbed harpoon, the bone needle, and the pottery found at the end of the Old Stone Age. He may have tamed the dog, and begun to keep the reindeer. Man was now a farmer. He used the bow and arrow, and knew the art of weaving. He set up villages on wooden piles driven into lakes.

The power of woman grew more and more While the men were busy hunting, leading herds, and fighting over rights of pasturage and stolen cattle, the wife began to till the earth. Soon, waving fields of wheat and barley were seen on the shores of the lakes. Man no longer lived on the hazard of the day. He had learnt to control the process of growth that went on around him. He acquired the use of mechanical appliances, such as the lever, but the discovery of agriculture was his greatest step towards civilisation. It made man settle down; families grew into village communities, and tribes and towns sprang up.

In the Stone Age man became a miner; he sank shafts in flint-pits and connected them by galleries. Then in the river-beds, he found pebbles containing copper, and became a smith. The Age of Bronze began.

Thousands of years elapsed before iron was used, but, meanwhile, the primitive wheel had been invented, and by the iron hand of war tribes had been shaped into nations.

Probably the mental power of the higher races was as high then as it is now; what was wanted was a scientific method of studying the properties of things. The Greeks arrived at an incomparable height of artistic genius, and Hero of Alexandria invented a kind of steam turbine, but nothing very important was added to the power of mankind till Watt made his steam-engine.

During the last hundred years the progress of man's con-

naked and thinnest-skinned of animals. He is not only without armour against living enemies or cold, he is also without weapons of attack. His teeth are practically worthless in this respect, not only on account of their small size, but also because his characteristic chin and the shape of his jaws make them singularly unfit for catching or grasping. For claws he has merely nails, capable only of the feeblest scratching; he can discharge no poisons from his mouth; he cannot envelop himself in darkness, nor change his colour, in order to hide himself; his speediest and most enduring manner is a breathless laggard.

The Boundless Possibilities of the Mind of a Man

Man is at first almost bereft of instinct, has to be burnt in order to dread the fire, and cannot find his own way to the breast. His sole instrument of dominance is his mind in all its attributes.

The applicability of mind is limitless. With this one instrument man achieves what, without it, could hardly be achieved—could not, indeed, be achieved—by a creature combining in his own person every kind of material apparatus, offensive and defensive, locomotor or what not, which animal and vegetable life have invented in the past. Man is a poor pedestrian, but his mind makes locomotives which rival the fish in the sea, the antelope on the land, and even the bird in the air; his teeth are of poor quality, but his mind directs his hands to supply him with artificial teeth, and enables him to prepare his food. One rhinoceros could dispose of fifty of him, and then of fifty more, but the rhinoceros will fall before his rifle; "by his devices he conquers the tenant of the fields." All the physical methods are self-limited, all involve penalties and hampering restrictions in some other direction, but the method of mind has no limits; it is even more than cumulative, and multiplies its capacities by geometrical progression.

The Supreme Expression of the Creative Forces of Life

Man, then, is his brain—more strictly, his neo-pallium. Not only is he it, but by it he lives, by it he has come into existence, by it alone he can survive. That is the least which can be said of it from the standpoint of biology.

Judged, however, not merely as the sole instrument of man's genesis and survival, but as the instrument of his mind, man's brain is evidently the supreme expression of matter, and of the creative forces of life. It is incomparably the most wonderful thing in the world, as it is incomparably the most complex. Before its structure and its functions the sun and the stars and the nebulæ hide their diminished heads and pale their ineffectual fires.

In the following chapters we must begin at the beginning—so far as we can discern it—and must follow some rational order. Man's body must come first, from its oldest to its newest—which are its most "nervous"—features. Thereafter we must proceed to study his ego, or self, which manifests itself through his body, beginning there also with the properties he shares with the ape or the ox, as he does his heart or his backbone, and going on to those which are all his own.

Meanwhile we have one more fact to discern. Given that the grey cortex of his brain contains the bodily elements which are new in man, and distinguish him from all other creatures, what is the psychical character of man which corresponds thereto, if any there be? Can we say that man alone has intelligence, while other creatures have only instinct at the most, and that his grey matter makes the difference?

The only Thing in the World that can say "This is I"

This absolute distinction cannot be made. Man is far more instinctive than we used to realise, and many of the lower animals are far more intelligent. The difference in man is no doubt enormous, and, of course, depends upon his brain, but it is only a difference of degree. Neither in the sphere of will, nor of reason, nor of memory can we discover any difference between man and his interiors which is radical, qualitative, explanatory.

The real and crowning mark of man, in virtue of which he is man, is that, while many or all other living beings are more or less conscious, at intervals or always, he is self-conscious; knows that "this is I," feels and knows himself to be himself—an ego, with a history and a destiny, "made with such large discourse, looking before and after," living not only in the here and now, but in the past and the future; not only in the outer world of space and time, but also in an inner world, no less infinite—for it is just as far to the innermost as to the outermost—of feeling and imagination, ideal and resolve; supporting his belief that there is somewhat in him which is "older than the elements, and owes no homage to the sun."

A GLORIOUS PICTURE OF HEALTH

ONE OF THE FINEST TYPES OF HEALTH—WHOLENESS AND HAPPINESS—IN MODERN PAINTING

"Diana of the Uplands," by the late Mr. Charles Furse, A.R.A.

THE DAY OF A HEALTHY MAN

The Desperate Battle between Health and Disease that goes on in your Body without ceasing

THE TRUTH ABOUT BEING PERFECTLY WELL

HEALTH—which is, indeed, the same word as wholeness and holiness—is what we all desire, whether we know it or not. Happiness is our being's end and aim, but it is certain that, except for very rare souls, happiness and also usefulness are impossible without health.

It is a necessity of our nature, nevertheless, that perfect health is an unattainable ideal. Even the man of mature and certain powers, generally supposed to be healthy, is yet inevitably, in the very act of living and enjoying his health, travelling along the road to more or less imminent senility and death. Our bodies are definitely born to die, and it is almost literally true that we die daily; parts of the body do literally die daily, and at every moment of existence the body contains poisonous products which it urgently requires to get rid of. It seems certain that this removal of waste products is either never quite perfect or else involves a slow deterioration, of which senility is sooner or later the upshot.

Perfect health is, therefore, no more than an ideal, but it is an ideal to be aimed at, and one which the fortunate and wise—but they need to be both—may substantially attain, and maintain even for several decades. Latterly, the standard of activity may require to be slightly lowered, but activity of the highest type, which is intellectual and moral, may maintain its standard, thereby implying a true health of mind, long after real health of body has gone for ever.

Our conception of health in this book is not to be merely physical, much less merely muscular, but is to include the whole man, body and mind; and our conception of the mind is not merely of the powers of reasoning—which are popularly and legally, but absurdly, supposed to be the whole mind—but also the sensations and emotions and desires, the will to do and the will to refrain.

The healthy man is neither he who can run ten miles, nor he who can resist infection, nor he who can maintain intellectual attention for hours without fatigue, nor he who is master of himself in all circumstances. The healthy man is he who has somewhat of all these qualities, and many more. It will begin to be evident already that wholeness means a great deal in this connection; and happy they be who find it!

So complex and various is man, so complex and various are his activities and the possibilities of his environment, that no description of health can really be adequate, because none can be all-embracing. Nevertheless, we may briefly describe, by way of a *minimum* indication, a healthy man's day and night; and though the description will consist largely of negatives rather than positives, yet it is very much the satisfaction of these negatives that makes an almost infinite number of positives possible.

Life, as Herbert Spencer taught us, is "the continuous adjustment of internal to external relations." Therefore, when we speak of health, we are assuming some particular or average state of external things; and from this point of view it will be seen that a man may exhibit robust and superb health, in a sense, when he is, say, in the very grip of pneumonia, or when he is lying in bed with a broken leg, or flying in an aeroplane, numb, dazed, and half blind, at sixty miles an hour. In each of these cases the man has been thrown by pressure of environment upon his deeper resources, and he may prove that their quality is superbly healthy.

The truth is that normally—that is to say, under such ordinary conditions as commonly satisfy us—we live actually upon the merest margin of our vital resources. Beyond this, we have, each one of us, a further supply which is never ordinarily called upon, and the quality of which we cannot ascertain,

nor can anyone ascertain, until we be tested. The depth of these resources also varies for different stresses in different people, and in the same person at different times of life. We have to think of life largely in terms of resistance, and one of us will resist fatigue much better than another, who, on the other hand, will make a better fight against starvation, or enforced lack of sleep, or exposure to cold. We all vary enormously, in deed, in our measure of resistance to different stresses; and it is far beyond the capacity of the cleverest doctor to probe the depth of our vital powers in all possible directions.

How We are Always, Day and Night, Testing Our Vital Powers in Many Ways

Yet we ourselves, live we never so wisely, are always testing our own vital powers in most important directions. We go from year to year, but are never called upon to show our mettle against extreme fatigue, or extreme cold, or starvation, or enforced lack of sleep. Yet every day and night of our lives we are exercising our vital forces in resistance against poisoning. This poisoning is partly due to dangerous constituents in what we eat and drink, or dangerous substances made from the food in our bodies. It is partly due to the products of the life of our own tissues, but it is chiefly due to the incessant invasion of our bodies by other living things, which seek to extend their lives at the cost of our own.

The existence of these creatures, which are nearly all of the class called microbes, has only recently become known; and the fashion in which they cause the greater part of all ill-health must clearly involve ideas of health which could not enter the mind of the student half a century ago.

The Healthy Man who goes through Danger with almost a Charmed Life

We meet these chief enemies of our health at every turn. We have only to scratch the skin to know that the microbes of "surgical inflammation" are almost omnipresent. The microbe of tuberculosis is present in about one sample in ten of the milk we drink; and if that milk has never been boiled or "pasteurised," these microbes enter our bodies alive, seeking more and more life at our expense. Practically all milk contains other microbes, possibly dangerous. Uncooked food is generally contaminated, and water, too. We inhale numerous microbes with every breath. Most dust is crammed with them notably the dust of the streets, and more notably still the dust of living-rooms, which the housewife so rightly fears, and, as a rule, so wrongly deals with.

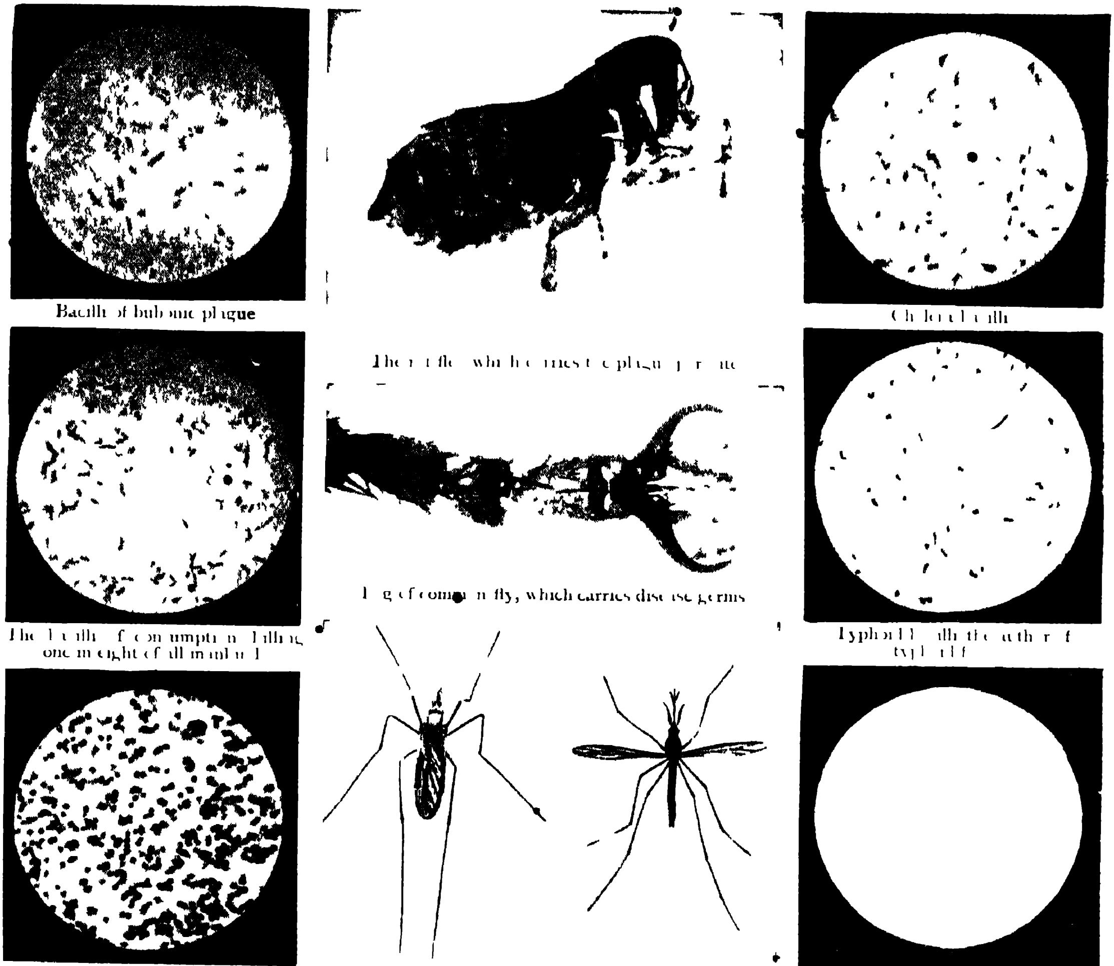
Yet, though possibly dangerous microbes exist in our mouths and throats and elsewhere, and though we are ever swallowing and inhaling new doses of them, we are mostly unhurt; and the healthy man walking through all these dangers bears what is almost a charmed life. Him only the most virulent can touch.

Nay, more. There are many microbes which, if they enter our bodies in large enough doses, or if they happen to be particularly poisonous, will certainly make anyone ill. Almost every child will "catch," or be caught by, measles and whooping-cough; and even the healthiest man, sufficiently bitten by a mosquito conveying the parasite of malaria, or by a rat-flea conveying the microbe of plague, will suffer from these diseases. Yet children often recover from measles and whooping-cough, and men recover from malaria, and even sometimes from plague. The remedy for these and a host of other microbe poisonings is natural, and may even occur on a definite day, as in the crisis of pneumonia.

How the Forces of Modern Science are Tracking Down the very Elements of our Health

Plainly, it depends upon powers of resistance; and if we are to distinguish between the man who inhales tubercle bacilli and kills them, and the man who inhales them to be killed by them; between men who catch a disease and men who, similarly exposed, do not; and between men who, having caught a disease, respectively conquer or are conquered plainly, we must reach some very deep and real meaning of the word health, and a meaning which applies to the daily exigencies of life as much as the capacity to digest food. It is just as important for health to digest one's microbes as to digest one's meals; and though the parallel is happy, it is also accurate, for vital resistance, and consequent health, mainly depend upon the production of ferments which digest and destroy invading microbes.

Since these new conceptions were finally established, with all that they involve for the health of present and future generations, we have gone further still, and have tracked down the very elements of our health in some degree. Metchnikoff has shown that the white cells of our blood are among the chief agents of our health, their daily and nightly duty being to search out and arrest and kill forthwith all manner of invading microbes. Metchnikoff therefore calls these white cells the phagocytes, or eating cells;



Bacilli of bubonic plague

The rat flea which carries the plague germ

Cholera bacilli

Leg of common fly, which carries disease germs

The bacilli of consumption, killing one in eight of all mankind

Typhoid bacilli, the cause of typhoid

The malaria parasite and the mosquito which carries it

The yellow fever mosquito carrying unknown parasite

SIX ATTACKING ENEMIES OF THE HUMAN RACE—DESTROYERS OF MILLIONS OF LIVES

The six circles stand for six of the greatest enemies of mankind. The white circle on the right still waits to be filled up with a photograph of the [illegible] of yellow fever [illegible] though we know the fly [illegible] The other five [illegible] disease we know [illegible] and we know that between them they destroy millions of human lives [illegible]

and poor fun, soon ended for ever is their owner's eating unless they well do theirs

The facts of health in its most important aspect can be actually seen under the microscope or upon the screen of a cinematograph. The healthy man, having gone abroad and incautiously exposed himself to the "night air"—in itself delicious and innocent—has been bitten by a female mosquito, which having helped herself to a drop or two of his blood, has left therein a memento in the form of a few malaria or "bad air" parasites These seek to multiply in his blood and there we can see health and disease in visible form, face to face—nay locked in deadly embrace. A drop of blood from such a man placed on a warmed slide displays Health his white cells visibly attacking, swallowing, killing, digesting, or utterly disintegrating in their own bodies the black parasites which mean Disease Half an hour looking at this scene and Health and Disease are realities henceforth for the rest of the spectator's life

One thing evidently is certain notwithstanding an almost universal illusion to the contrary, and it is this that health or vitality and mere muscularity have no necessary relation to one another at all. It may be admitted that the muscles of a given person are fitter and show better tone—as for instance, the tell-tale muscles of the face—when that person is in good health than when he is not but this is a vastly different thing from saying that health is to be attained or maintained by muscular development It is true that physical exercise may promote health, as by improving the

breathing, aiding the digestion, diverting the mind, avoiding *ennui*, facilitating sleep, driving dull care away. These are valuable ends for health, but it is not a question of the number of inches round the upper arm.

A final and overwhelming argument against the view that muscularity and vitality are convertible terms is furnished by the contrast between the sexes. Woman, according to that view, is less healthy or has less vitality than man. She is, in the hallowed phrase, "the weaker vessel." Nevertheless, at all ages, under equal conditions, the death-rate among women is lower than among men. We find two or three women centenarians for every man of a hundred.

"The Great Vital Power of the Frail Little Woman who Nurses Hercules"

All through life woman's vitality is superior to man's. She will resist starvation better, or exposure to cold, or exposure to heat; she will survive a far greater loss of blood, far more poisoning, far more fatigue.

On all counts and at all ages, whether one day or one hundred years, the female organism, which is the less muscular, has a greater fund of health than the male organism. The contention as to muscularity, therefore, breaks down on the first examination; muscularity and health have nothing to do with each other. Your Hercules may be ridiculously susceptible to a cold, a baby at bearing pain, a certain victim to the first microbes of pneumonia that come his way on a cold night; and the frail little woman who nurses him, of whom he could overpower a dozen, will survive him at any vital test which can be named.

All this is not to say that the muscles are not worth exercising; least of all is it to say that the forms of muscular exercise which are involved in play and games, especially in childhood and youth, are not worth while. All modern psychology teaches us with increasing emphasis that play and games are the normal work of childhood, and that they are definitely constructive of nervous and general health in the future, the impulse to them being as normal and healthful as the impulse towards food. But that does not lead us to the monstrous and incredible theory that physical exercise is the royal road to health, or muscular capacity the index to it.

When the Healthy Man Wakes Up in the Morning

And now let us consider a night and a day in the life of a reasonably healthy man. From it we can predicate nothing for certain as to how he will face an attack of pneumonia or a staggering grief, but, at any rate, he is better to spend his time as here described than otherwise.

When the healthy man wakes in the morning he does so spontaneously, for the excellent reason that he has had enough sleep, his brain is completely recreated, all the fatigue-poisons of the previous day have disappeared, and the brain is ready and anxious for spontaneous activity once more. The awakening may be sudden or gradual—that appears to be a detail of the individual—but it is at any rate natural, and of internal origin. Further, if the waking be gradual, it should be entirely pleasant—a feature, indeed, which characterises the healthy man's proceedings at all times. In some fortunate people this waking period displays unusual forms of mental activity. They get ideas then, write good lines of verse, compose musical phrases, or conceive brilliant dialogue or good plots for stories.

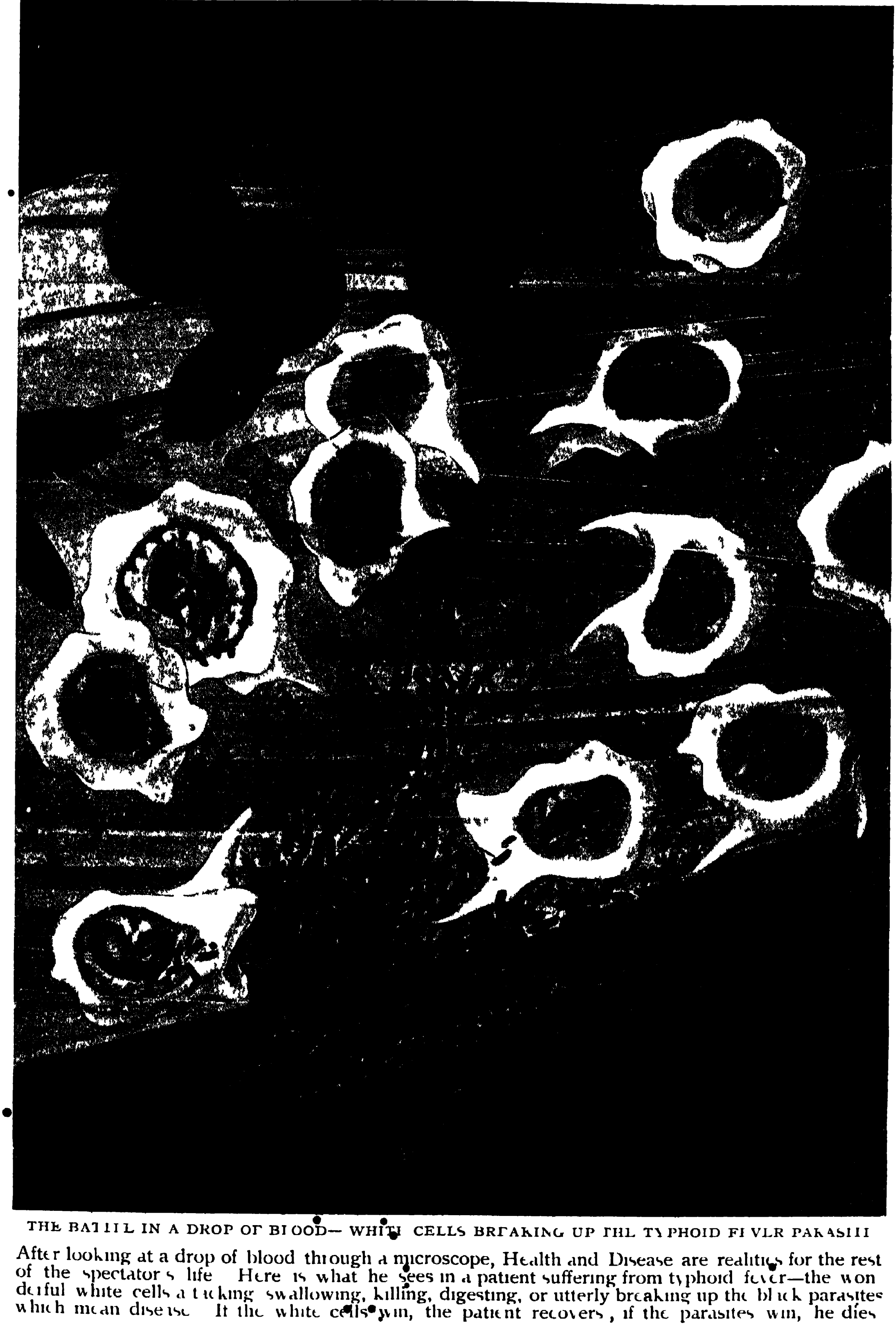
Apart from this, the healthy man, on waking, has no recollections of any state of partial or entire consciousness later than a few minutes after going to bed the night before. In other words, he has had a night of continuous sleep of the priceless kind which involves no dreams deep enough to be remembered on waking. It is certain that we have many dreams which we do not remember; it may even be that there is no such thing as a dreamless sleep, except under the influence of a drug. But our dreams should be so superficial, so to say, and so vague and incoherent, that no memory of them is retained on waking.

The Healthy Man who Leaves his Bed as he would Leave a Prison

We differ naturally here, as in all other respects, and there are, perhaps, some people who can never obtain sleep of this quality, but they should not be too certain that it is impossible for them. The probability is that broken sleep, or sleep which does not come quickly, or sleep complicated by remembered dreams, owes its poor quality to strain either upon the brain or the stomach, or both, before sleep was sought.

The next fact about the healthy man awake in the morning is that he now wants to be up and doing forthwith. He has had bed enough, and he no more wants to stay there than to be in prison. It may or may not be that he wants his breakfast. That is not a matter of any significance for health, for it depends upon habit. There are plenty of people to prove that the best way to begin the day is with a hearty breakfast, and there are as many to prove that the

HEALTH & DISEASE IN DEADLY COMBAT



THE BATTLE IN A DROP OF BLOOD— WHITE CELLS BREAKING UP THE TYPHOID FEVER PARASITE

After looking at a drop of blood through a microscope, Health and Disease are realities for the rest of the spectator's life Here is what he sees in a patient suffering from typhoid fever—the wonderful white cells attacking swallowing, killing, digesting, or utterly breaking up the black parasites which mean disease If the white cells win, the patient recovers, if the parasites win, he dies

"no breakfast plan" has made new men of them. It matters not. One may arrange one's nervous rhythm in any fashion—for breakfast on rising, or for breakfast three or four hours later. This much may be said, however: if it is the healthy man's rhythm to have breakfast on rising, then he is ready for it, because to have a regular and keen appetite is part of health. It has to be added, however, that there are conditions attaching to this appetite. In the first place, though variety in food may be welcome, it is not necessary, and the appetite is for food itself; that is to say, it is a genuine hunger, and not merely a wish for scents and tastes in the food. Dry bread, for instance, may taste delicious.

Scarcely less important, both to the man himself and those with whom he lives, is the fact that, though he is ready for breakfast, he is not desperate. He retains his equanimity if it be delayed. "Tempers are short in the morning," but his is not. He has slept deeply and well in pure air, and does not display the "breakfast temper" either in waiting for the meal or should there be an untimely interruption during its course; he is "master of himself, though China fall."

How Long should the Healthy Man Sleep?

At this point the reader may say that we have forgotten something. How long did the healthy man sleep? To this the reply is that a doctor neither knows nor cares. If we know its character and its fruits, we need not be in the least concerned about the duration of his sleep; it may have lasted five hours—nay, in an old man, it may have lasted four; or it may have lasted nine. People vary individually in this respect, and it is extremely probable that we can train ourselves to squeeze more sleep than formerly into a given time. Sleep cannot, indeed, be measured by the clock, for though that will give us length it cannot give us depth, which, of the two, is the more important. The old proverb says that an hour's sleep before midnight is worth two after it, and another says that health and other things follow upon the practice of "early to bed and early to rise." These statements are not true, though they are sufficiently connected with the truth to be useful as a general doctrine. What is true is that the earlier hours of sleep are much deeper and therefore more valuable than the later hours, as careful experiment has proved.

Also, there is much to be said for the doctrine: that if we have a usual hour for bed, it is better not to be much later. Not the absolute hour but the regularity is the thing that matters, though even this is a rule some people can defy with impunity.

Now the healthy man has work to do, not necessarily for money, not necessarily—if indeed possibly—too irksome, but work nevertheless, and certainly work which involves some measure of effort and entails some vital expenditure. We know this for certain about the healthy man, because we know that no one who has not pleasant and congenial work can be healthy at all.

The Importance of a Change of Interest before you Go to Bed

It is probable that, if the healthy man's health is to be maintained, his work must be of a kind which, whether in itself or because of some ideal end which it serves, exhilarates him even while it makes demands upon him; and it follows from this that it must be work adapted to his particular capacities and tendencies. Road-making is in itself a useful and worthy thing, but it may not be ideal work for all undergraduates, John Ruskin himself notwithstanding. Another point to be noted is that, no matter whether the work be making a book or a road, it is given up in time for the healthy man to change his interest before he goes to bed. This will be his heart's desire. It may take the form of bad singing or worse verse; it were well to take the form of a romp with his children—whom the healthy man, in the full sense of the word, can scarcely but have, but, whatever it be, it is spontaneous, and therefore in the nature of play.

The Things that the Healthy Man Does Not Do

Throughout this period, while our friend may have had his anxieties and fears of a reasonable kind, he has had nothing that can be called "carking care," no forebodings or presentiments, no worry in its literal sense of the emotion which strangles the life. About others and their health he may have been concerned, but his own has not entered his thoughts. During the whole of his conscious day his health has been marked not only by positive achievement, but by certain notable negations. He may have occasionally been bored, or even pleasantly tired, but never weary. Of course, he has had no pains of any kind, neither headache nor backache, nor even "hunger pains," if he found it convenient to miss a meal, which the healthy man can do without inconvenience at any time.

Throughout the day, not only has he never given a thought to his own health, but he has been totally unconscious of his own person, and all its parts, save incidentally, when washing and dressing; and even then not quite consciously, for his mind was mostly elsewhere. He has, of course, never once thought about his digestion; and if he were asked about that subject he could afford no further information than that at intervals during the day he enjoyed depositing certain fluids and solids in the largest aperture of his face, but that of their subsequent history he has no record whatever. As for his tongue, he does not remember ever having seen it—he would as soon carry a pocket-thermometer; and indeed he inclines to the healthy view that tongues—unlike children as our ancestors misunderstood them—should be heard and not seen.

It need hardly be said that the healthy man swallows no medicine, not even a dinner pill. He needs nothing but food and water. His thirst is thirst, and not a crave; his hunger is hunger, and not an itch. He may have taken a small quantity of condiments—other than salt, which is a true food—in his diet, but he did not need them.

The Healthy Man who Eats and Drinks What and When He Likes

His diet was smaller in amount than most of the well-to-do are nowadays content with. This is partly due to the fact that, being healthy, he utilises all the nutriment he consumes, but still more due to the fact that his desire for food is true hunger—such as many of us have not experienced for years—and also to the fact that he did not stimulate it by any artificial means. Not only is his total diet small, but the quantity of meat in it is conspicuously so, while sauces and soups and gravies have all been somewhat neglected. It is probable, also, that he has retained the sweet tooth he had as a boy, but most men nowadays have lost their appetite for sugar, which is such an admirable food, owing to their taking alcohol. Most men who neither drink nor smoke retain the liking for sweet things, which is characteristic of a healthy appetite. The Germans and the Japanese have just increased the quantity of sugar compulsory in their soldiers' diet.

Let us understand clearly that in his eating and drinking our friend is not following a theory or a textbook, or a medical adviser, nor is he in the least aware of exercising any constraint over himself. On the contrary, he eats and drinks what, as, and when he likes. The healthy man neither takes nor requires any so-called stimulant. Indeed, though in a sense our healthy man is distinguished by nothing more than by his self-control, this self-control involves no real struggle or injury or distress. Having no morbid appetites to deal with, he is without any need for self-control on that score. Being healthy, he is, throughout his entire waking life, blessed with that subtle but priceless form of internal sensation which is called by the psychologists "the sense of organic well-being."

The Man who is Full of "Go" and Blazes on Occasion

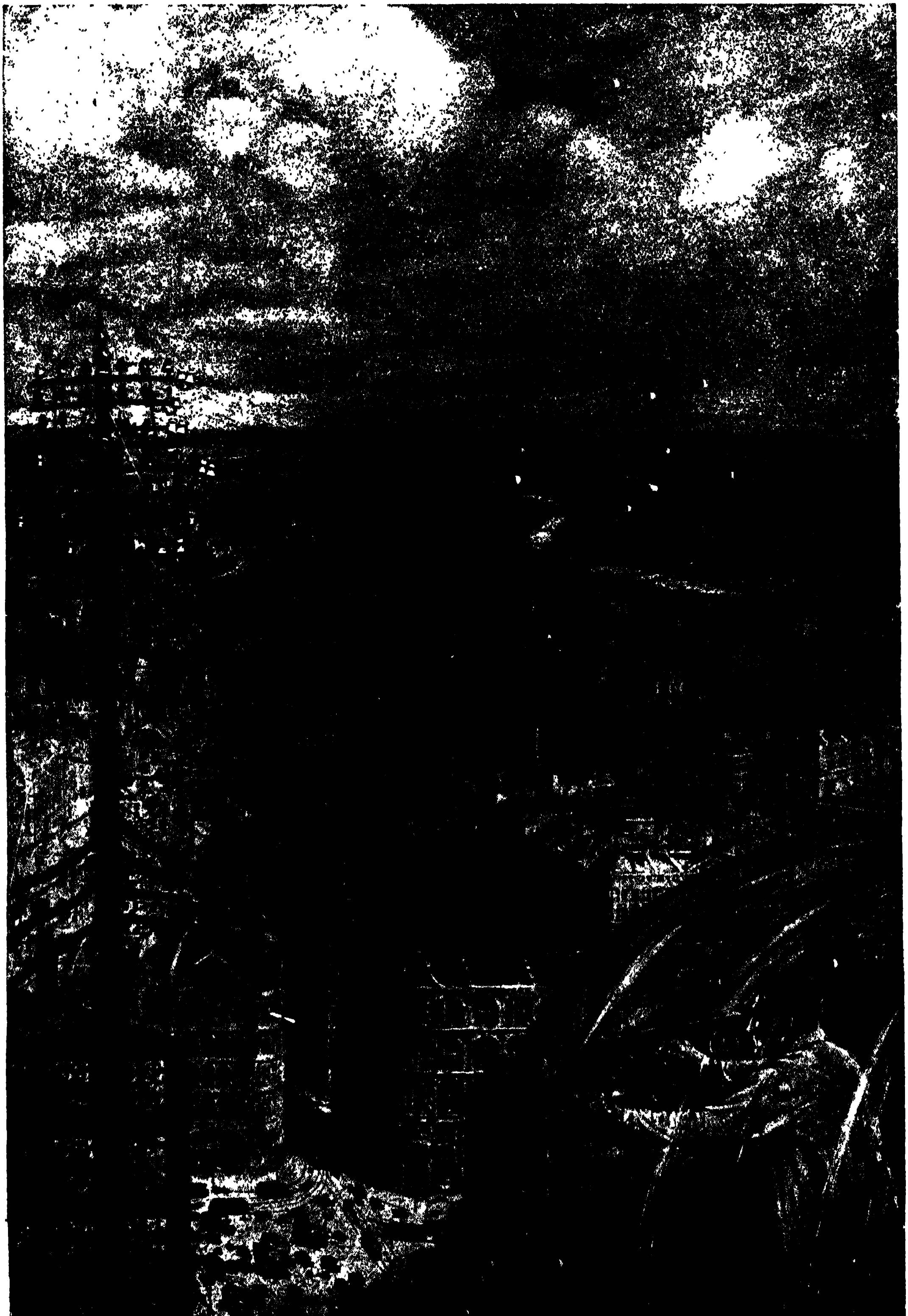
He is not overworked nor worried. But from these fortunate conditions of health it follows that the task of keeping his temper perfectly throughout the day is really not a task at all. In no pain or distress of mind or body, having his subconsciousness pleasantly irradiated with the "sense of organic well-being," which is the bliss of the convalescent, how can he lose his temper for any small cause?

This is by no means to say, however, that our healthy man is somewhat of a vegetable; a useful machine, but rather clockish and stockish; placid, "safe," but somewhat lacking in colour and certainly not "intense." On the contrary, the healthy man is definitely and necessarily active. He is full of "go," and ready to blaze up on occasion; but when he blazes he burns things that want burning, and does not merely get red in the face and then subside. His health provides him with considerable self-confidence and a measure of what may be called organic optimism which sets him going, very readily, on all manner of enterprises; nor is he unduly depressed if they go wrong. He does not jump at the slightest sound, nor construct burglars in the night from creaking furniture, but his senses are entire and keen, and give him satisfaction in the using.

When all the Forces of a Man say "Let us be at it again"

He gets through an astonishing amount of work, and likes it; and he is never more active than when he "takes a day off." He goes to bed regretfully, for there are heaps of things he would love to do; yet when he gets to bed, being perfectly confident that he will soon sleep, he promptly does so, and scarcely stirs until the forces within him say: "Now let us be at it again." He may be poor or rich, humble or exalted in station, but if he answers to this description he is the happiest man alive; nor need you ask *him* whether life is worth living.

IN THE ELECTRIC CITY OF THE FUTURE



In the electric cities of the future one man with his finger on a lever will be able to control the stream of power which does every kind of work required by the community; one man, that is, will "drive the town."

MAKING THE WORLD ANEW

The Discoverers and Inventors who are Transforming the Earth and Liberating Mankind for a Happier Life

THE NEW POWERS AND IRON SLAVES OF MEN

MAN is making the world anew. For perhaps a million years and more he has struggled in ignorant misery with natural conditions, but at last he is emerging victorious. In his new knowledge of the laws of Nature he has found a key with which he is unlocking the gate to a larger and a happier life.

There are yet many people who do not discern that everything about them is altering; but those who open their eyes and their minds know that the power of modern science is slowly transforming the world. Human life is becoming a divine and lovely thing; poverty is passing away, and disease; and man, by constructing iron slaves to perform the drudgery of labour, is liberating himself for a higher, freer, happier, and more creative existence.

At a leap man has grown, as it were, from an ant into a giant. A few hundred years ago he still used only the simpler forms of the lever in the most ingenious of his tools; animal strength was his chief source of extra-human power; and the most ingenious of his machines did not greatly increase the might of his hand. But now he has quickly gone on extending his knowledge and the marvellous power born of knowledge, until he stands dazzled and bewildered at the spectacle of the tremendous forces he is now gathering into his hands.

Were he but now to begin, manfully, confidently, carefully, to use all these forces with a sound knowledge of their range and quality, he would be able, perhaps, in the present generation, to enter into the Kingdom of Man. He could make the earth his footstool; and thence he might rise, from his study of the heavens, master of the mysterious power which fills the spaces of the universe.

But at present our ideas are not commensurate with our powers. We are like a starving man who has suddenly come into an immense fortune without knowing it. That is why we are still apt to see only the darker side of the age of transition in which we live. For a hundred years we have been making the worst of the best of all possible worlds.

Instead of using, for instance, the mighty power of the steam engine with the large vision and the steady forethought it required, we have allowed it to produce on human society the disastrous effect of a blind force. The growth of our great cities, the rapid populating of America, the expansion of our colonies, the entry of Japan and China into the field of European politics, are among the direct consequences of a trivial event in Glasgow in the middle of the eighteenth century. A model of the pumping engine invented in 1705 by an Englishman, Thomas Newcomen, and already used in a few instances to drive machinery, was taken to an ingenious mathematical instrument maker to repair. When it left the hands of James Watt, in 1769, the engine had been transformed into a mighty power which has produced over all the world a revolution compared with which the French Revolution has no historic importance.

Put on wheels this wonderful thing became the steam locomotive; placed on a boat, it developed into a marine engine; installed in mill and factory, it armed the feeble hand of man with a force to which no limits could be put, and laid a sure foundation for all those future miracles of mechanical power which are to redeem mankind from the harder and duller forms of toil.

Certainly the steam engine has been a great power for good, but much harm also it has done. It has created the industrial slum—the foulest blot that ever existed on

this fair green planet of ours. It has brought about a degeneration of some large sections of our working population. For seventy years villages have swiftly grown into immense, sombre, and unhealthy cities; and though this growth was almost entirely due to the controllable force of the steam engine, no statesman ever tried to make the development orderly, well-planned, and conducive to the general welfare of the race. So, as man failed to exercise his newly won command over Nature, the forces he mishandled were turned against him. Nature has still one deadly weapon left against her rebellious son—the weapon of disease—and she has used it ruthlessly.

The Defects of Civilisation which are the Main Cause of Disease

The reader will probably be surprised to learn that there is practically no disease in a state of nature. Disease in both man and animal is the symptom of a defective civilisation. Nearly all maladies are produced by microbes, but these parasites live in the blood of wild animals without producing any illness. It is only when man brings his domesticated races of sheep, cattle, pigs, and horses into contact with the microbe that disease originates. It is the same with the plants that man cultivates for his own use. In a wild state, and in their natural soil, the wheat, the potato, and the vine are not hurt by the epidemics which sometimes produce a famine in civilised lands. The fittest in each form of life have been selected by a long, fierce struggle for existence, and brought into a condition of adjustment to their circumstances. Probably primitive man was in the same case. He became subject to disease when, in attempting to build up a civilisation, he set himself to interfere with the delicate and efficient balance of Nature.

The Power of the World To-day to Abolish every Epidemic Disease

In a perfect civilisation man, and the animals and plants he uses, would be as free from disease as they are in a state o nature. Means are not wanting to bring about this happy consummation. It has been calculated by Sir E. Ray Lankester that, by the application of known methods of research and prevention and cure, every epidemic disease could be abolished within the next fifty years. Another eminent man of science, Professor Metchnikoff, of the Pasteur Institute, has recently discovered, after many years of study, that what now passes for senility is a microbic disease. He has even found the microbe which brings about this premature death, and it is more than possible that he has also discovered a method of prevention which will enable man to live, in full possession of his faculties, twice as long as he does now.

This new power over disease is surely the most important of man's achievements. Without it his triumphs in every other field would but throw a sunset splendour over the history of the human race. Mankind would indeed resemble a young man of genius, such as Keats, who, fatally stricken with consumption, died at the moment when his power promised to equal that of Shakespeare. Now, however, we can look forward with a strong and steady confidence to the future. Not only have we at hand the means of subduing the strange and invisible armies of death, but we have gone on in the last few months to harness some of the microbes and make them win us our bread.

A few years ago a famous man of science excited serious apprehension by raising the problem of the food resources of the world. One of the capital effects of the modern industrial revolution was to increase in an extraordinary manner the population of some of the more progressive races.

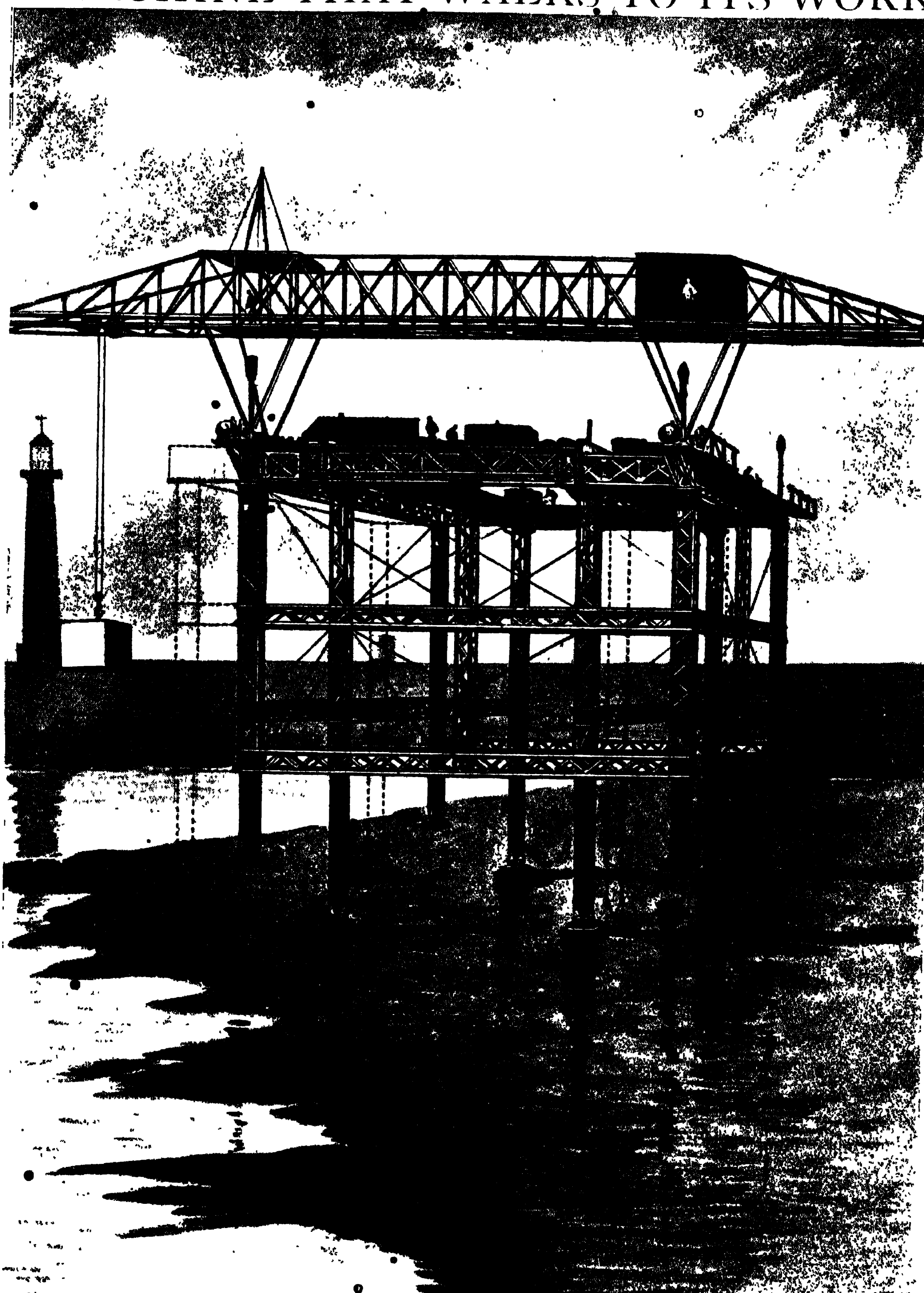
The Prospect of an Overcrowded World Driven to a Desperate Struggle for Food

The large vacant spaces of the earth were quickly peopled, and transformed into great hives of labouring humanity. Abundant food was obtained for these pioneers in the large tracts of virgin soil on which they were slowly advancing. Their advance is now almost at an end; there is no more empty land ahead of them.

Yet in the places where they first camped, on the prairie or in the forest, have sprung up huge towns resonant with the roar of machinery and loud with the traffic of long, dark, streaming crowds of workers. Thus in the last ten years there has been a universal rise in the price of many of the necessities of life, owing to the general increase in population being out of all proportion to the increase of new wheatfields and new pasture lands.

So on this economic fact there was lately built a gloomy view of the prospects of the human race. The conquest of disease, it seemed, would only aggravate the ultimate difficulty, for by enabling man to live and breed in greater numbers science would only hasten the day when a desperate humanity, brutalised by overcrowding and the struggle for food, would return to the most savage form of warfare.

A MACHINE THAT WALKS TO ITS WORK



A HUGE STEEL STRUCTURE WHICH WEIGHS 200 TONS, AND MOVES STEP BY STEP AT 40 FEET AN HOUR

This platform, carrying a massive electric crane, has two frameworks, one inside the other, each with four legs. It stands on its outer legs, as shown in the picture. When it is to be moved, the inner stage slides forwards or sideways by electricity, and the legs are lowered to the position of the dotted lines. The outer stage then slides forward, the legs rising and falling, and carrying the stage onward.

It was a wild prospect — a tragic vision of the mightiest and most widespread of civilisations expiring by over-population.

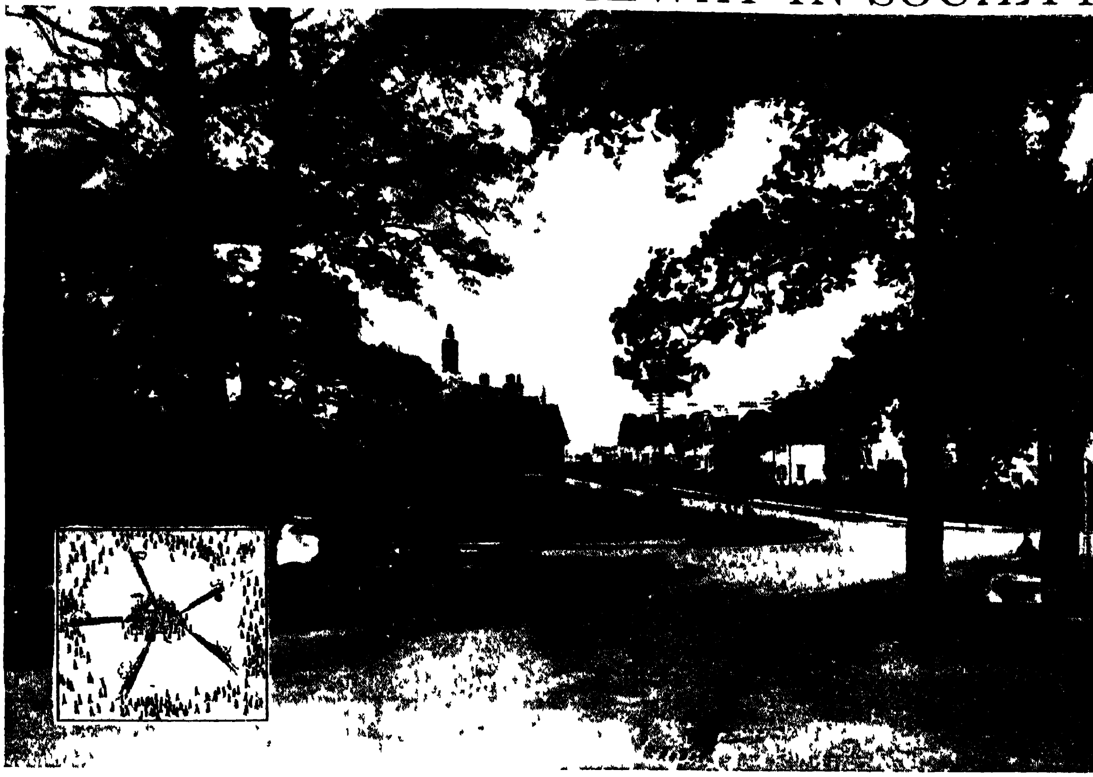
But the ghastly nightmare has now vanished before an apparently slight discovery in the study of a microbe! Plants feed on nitrogen. Up to the present we have let them find most of their food themselves. When they could not find it, we regarded the soil in which they were planted as infertile, and troubled no more about it. Now, it seems, we can arrange to feed the vegetables we wish to foster. The earth is largely composed of waste nitrogen; there is more of it than the human race will ever require from which to grow food. The question is whether free nitrogen can enter vegetable tissues, and whether certain microbes can continually provide the nitric nitrogen on which alone vegetation can feed. Experiments are now being carefully made. The results are not yet fully known, but they are so promising that it is certain that a new intensive kind of agriculture will be used in all farming operations of the near future, and that the human race, however it increases, will never fail for want of food.


THE VAST POWER OF NORWAY'S WATERFALLS
equalling the power of eight million horses, and now being rapidly developed with the prospect of building up for Norway a great industrial future.

Yet, though the nightmare of diminishing food has vanished, it has done good service by stimulating thought about another matter of vital interest. Eugenics, the science of breeding sound and able human beings, existed, in fact if not in name, before Sir William Crookes directed attention to the problem of our food supplies; but this problem, in its connection with over-population, helped to make eugenics a matter of popular concern. Many people began to ask how it was that the more advanced communities of civilised men did nothing to prevent the multiplication of the unfit, especially of those poor stricken men and women who hand down to their children the seeds of terrible diseases. The reply was rightly made that man could not control the reproduction of his species until a thorough investigation had been made of the laws of breeding and heredity. It seemed as though this investigation had only been carried out roughly by breeders of animals and horticulturists; but fortunately some precious discoveries had been made about forty-five years ago by an Austrian abbot, who had been unable to obtain a hearing from men of science in his lifetime, and whose achievements were lost to the world. Some of his papers, however, have now been found again, and on them has been established a new science of heredity and breeding — known as Mendelism, after the Abbot Mendel —to revolutionise agriculture and stock-breeding. This new science promises also to throw much light on the mysterious processes of human life, and thus give man a strange power over the future qualities of his own race.

During the time in which these advances have been made in the control of the forces of life and death and birth and growth, a wide and far-reaching progress has been achieved in many more directions. New discoveries of great importance are taking place almost daily. The entire foundations of physical science have lately been re-laid by Sir. J. J. Thomson and his fellow-workers. It is not extravagant to say that

THE POWER OF A RAILWAY IN SOCIETY



THE PLEASANT WAY IN WHICH IT IS POSSIBLE FOR PEOPLE TO LIVE WITH A FAST RAILWAY

THE SLUM INTO WHICH A SLOW RAILWAY DRIVES PEOPLE TO LIVE

A good or fast railway is a centrifugal force, spreading people out, as shown in the top diagram; a bad or slow railway is a centripetal force, drawing people in, as shown in the diagram at the bottom. A good railway helps to build up population in the countryside; a bad railway helps to make slums.

there are at present among us men of science who may rank with Sir Isaac Newton. We live in an age of intellectual giants; an age of splendid achievement, of glorious inspiration, of magnificent prospect, full of ideas of large scope, capable of exciting the mind to noble enthusiasm.

We are living in the veritable Renaissance. Compared with it, the revival of learning in the fifteenth and sixteenth centuries was but the faint glimmer of dawn; the stir of new thought in the seventeenth century, the movement of enlightenment in the eighteenth century, were only a distant gleam of the break of day. Now has come full noon; the light of the new knowledge shines over all the peoples of the earth.

The New Knowledge which is Awakening the Intellect of Sleeping Races

Under its kindly influence the intellects of the races of the Far East have awakened from sleep; and in Japan great men of science, like Kitasato, are appearing and working in friendly rivalry with the best minds of the European world. In modern science all the higher races are finding common ground where they can meet and understand each other, and work together for the good of mankind.

The unification of the human race is now, for the first time in all history, in course of being accomplished; and chief among the factors concurring to this happy end are modern science, the industries born of science, and the vast and subtle web of commerce and finance produced by the growth of industrial power. The great wars of a hundred years ago are now becoming a practical impossibility. So closely interwoven are the trade and traffic and money markets of the higher nations that a successful campaign against any great Power would now almost ruin the conquering state. As Norman Angell has pointed out, the military seizure or destruction of the wealth or trade of one nation by another has become an economic impracticability.

Men so Busy Fighting Nature that they have no Time to Fight Each Other

For, owing to the delicate interdependence of the modern international credit system, the collapse of the vanquished race would necessarily involve the conqueror. Indeed, even an attempt to place a defeated people at a commercial and industrial disadvantage would now react very injuriously on the victorious country. The means of instantaneous communication developed within the last thirty years has made the system of international credit so overwhelming a political force that no navy or army can ultimately prevail against it.

All this is an unforeseen and extraordinary result of the harnessing of the strangest and mightiest of natural powers —electricity. It is the telegraph and the submarine cable which have created the delicate fabric of international credit on which now depend the peace and prosperity of nations. Why was it that no wild, ruinous civil war lately took place in Mexico? Because the pacific interests of the Mexicans are vitally and intricately connected with the pacific interests of the United States and Europe. The whole civilised world is growing into so huge a workshop that any serious disturbance in any part of it cannot be permitted. So busy are men in fighting Nature that they have no time to fight each other. Mammon himself has been transformed into a policeman, entrusted with the beneficent work of keeping the peace of the world.

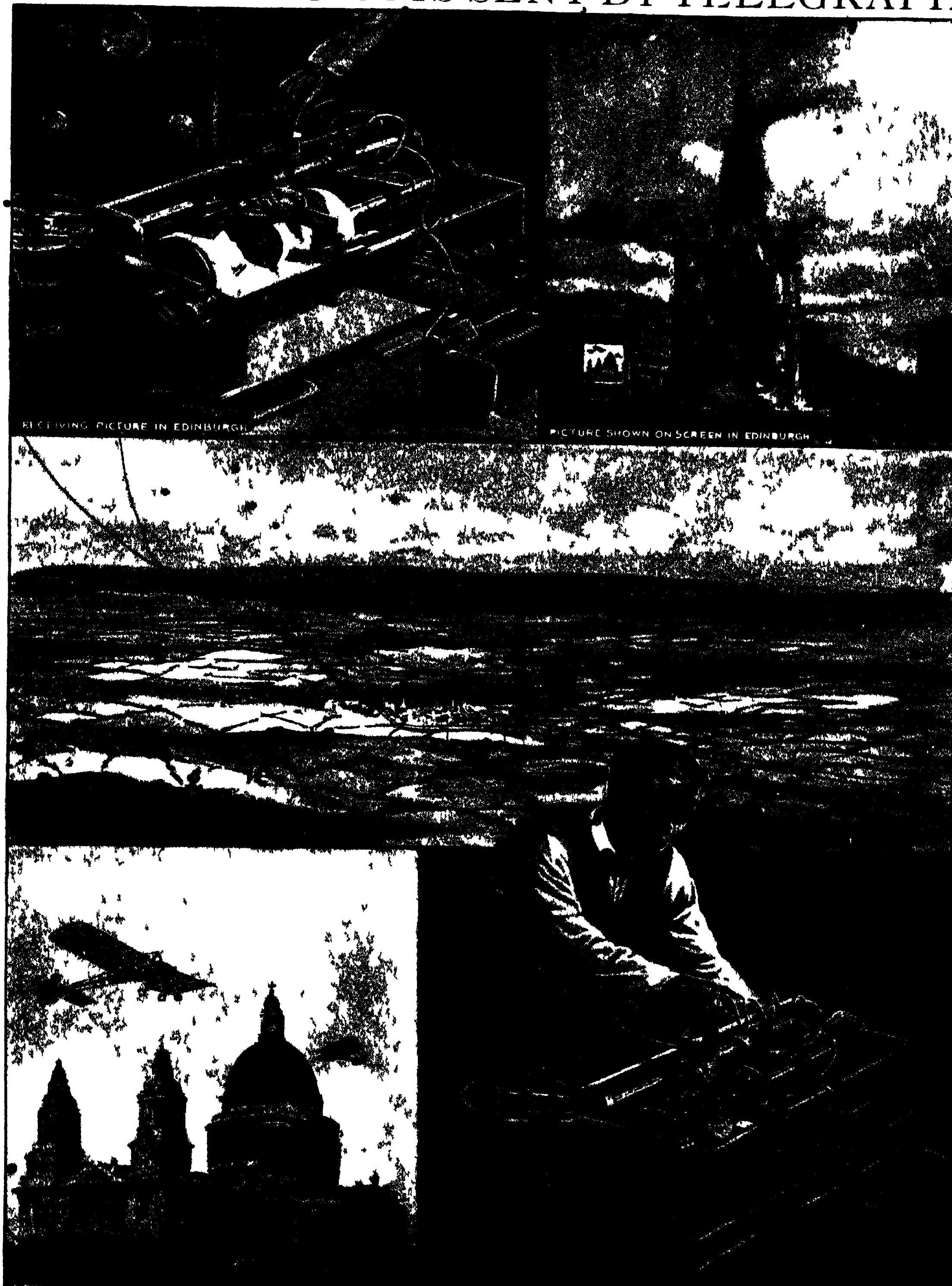
And during this peace, what high and fruitful things are being achieved! We are spectators of a battle for industrial power between steam and electricity. There can be little doubt that electricity will in the end prevail. At present, however, the invention of the turbine seems to have given to steam a new lease of life. It is the most important step in engineering since the days of Watt.

The Marvellous Horse-Power that Lies in the Coal Mines of the World

Applied first to the driving of dynamo-electric machinery, it is now being used to revolutionise navigation. By means of the turbine, steamships have been transformed into travelling towns, speeding across the ocean at a record pace, and bringing Europe and America nearer together than London and Edinburgh were 200 years ago.

It is probable that the next great advance in the power of steam will be effected by some kind of internal combustion engine. At present steam is made by what is practically the primitive method of putting a kettle on a fire. This means an extraordinary waste of energy. If, however, a way were found of putting the fire inside the kettle, all the heat would be used in transforming water into steam. Then, if the steam power were directly applied in turning the vanes of a shaft, as is done with a turbine, steam power might for ever remain one of the grand forces of mankind. The steam-engine is fed by the coal-bed, and there is still available in the mines of the world enough coal to create fifteen billion horse-power for 12,000 years. This estimate will

HOW A PICTURE IS SENT BY TELEGRAPH



RECEIVING PICTURE IN EDINBURGH

PICTURE SHOWN ON SCREEN IN EDINBURGH

SCENE IN LONDON

TELEGRAPHING PICTURE IN LONDON

A photograph is made up of tiny portions, lights and darks. By placing a prepared picture on a revolving drum under an electric needle, a current can be passed through the light parts of the picture without passing through the dark parts. These currents travel to another revolving drum on which a piece of chemically sensitive paper moves under a second electric needle, and the needle makes a black mark where the current flows, leaving the paper white where no current passes. So a positive picture may be built up dot by dot on the receiving machine from the currents governed by a negative picture on the transmitter, and so a picture of a man flying in London might be shown on a screen in Edinburgh before he had finished his flight.

BRINGING MUSIC FROM THE AIR

THE PRINCIPLE OF THE PIANO PLAYED BY AIR, EXPLAINED IN A PICTURE-DIAGRAM

The power of the air is being used in a hundred ways in the modern world, but no more ingenious application of air-power has been conceived than the way which enables a child to play the piano without knowing a single note of music. By a simple process of admitting air through a small hole in a music-roll, so as to enter a hollow bar and act on a bellows, lift a lever, and cause a hammer to strike a key, the mechanical piano has been made an established institution in the last few years.

surely be greatly increased when all the coalfields of the earth are discovered.

Yet the age of coal and steam and the smoky industrial cities which they have produced is even now about to pass away. For the era of electricity is at hand. As Sir William Ramsay has recently pointed out, it is now possible economically to convert coal at the pit-mouth into electrical energy, by using turbine or gas engines, and then by means of wires to distribute the electrical energy to the place where it is needed. We are still waiting, it is true, for the invention of the grand instrument in the general use of electric force—a cheap, light, easy means of storing electricity in considerable quantity. Some of the most ingenious minds in every progressive race are busily searching for the storage battery which will make electricity the most useful and powerful and varied of all the forces in the service of man, so that it is likely that this very important discovery will be achieved during the present generation.

Already Mr. Edison, it is stated, is about to revolutionise our means of urban traffic by substituting for the petrol-driven motor-car and omnibus cheaper and more efficient electrical vehicles with a new kind of storage battery. It is not merely through a few inventions of importance that man is adding to his powers. Countless small new devices and new discoveries are increasing the convenience and pleasure of civilised life. Many of these new devices are so simple that no one stays to explain them, and they often remain mysteries even to many who constantly use them. With regard to the means of travelling, for instance, how many cyclists understand the mechanism of the free wheel, which has added the new delights of "coasting" to one of the most popular forms of open-air exercise? As will be seen in the picture-diagram on page 88, a little arrangement for releasing a pawl from a ratchet constitutes the secret of the free wheel, which has revolutionised the art of bicycling.

FLASHING A MESSAGE WHICH COULD BE PICKED UP ANYWHERE ON THE PACIFIC OCEAN

As soon as we can store electricity in any large amount we shall be able to return to one of the most primitive sources of energy, the windmill. Contrary to popular opinion, the power obtainable from the wind is very considerable, and, simple though the windmill is in construction, it is an admirable machine for the purpose. The only disadvantage of wind power is its intermittent nature, and the cost of storage.

Similar disadvantages seem to attach to all the actual instruments invented for harnessing the powers of the moon and the sun. The tides caused by the swing of the moon might supply energy if they could be transformed into electric power and distributed in a regular flow from a reservoir; the same remark applies to the varying heat of the sun, though in our cloudy climate perhaps little power is likely to be derived from the direct utilisation of solar heat. What is wanted is a new and efficient means of obtaining constant and adjustable sources of energy; and the forces of wind, tide, and sun-rays must go on running to waste until the great storage battery is discovered.

In the meantime, electricity is already in course of changing for the better the conditions of our urban life. In places where there is a large supply of natural power, a new kind of town is appearing.

The Pleasant Kind of Town that People will Live in More and More

No forest of factory chimneys darkens the sky and defiles the air of these new towns with evil fumes; no coal fires in innumerable ugly little houses fill the rooms with dust, and thicken the winter fog and soil the summer heaven. Everything in these new towns is sweet and clean and healthy. Flowers grow in beauty around the cottages of workmen, and among the flowers are happy children with rosy cheeks and clear, bright eyes. A single current of electricity does all the harsher toil. Born in a strong stream of water falling from some mountain and swirling a few miles away from the town, the electric force runs along a cable to some distributing house, and thence through a network of wires into every building. At night it fills the streets and the dwelling places of the people with light; it can do all their cooking; it links them closely together by telephone and telegraph, and enables them to speak with people hundreds of miles distant. It drives every piece of machinery, and makes even the factory a bright and healthy place of toil. And how docile this terrific force has become! In the electric cities of the future one man with his finger on a lever will be able to control the stream of subtle power for every kind of work required by the community.

Already the cheapness and the infinite utility of electricity are effecting an important change in the industrial power of various countries. Mountainous lands which have been unable to compete with the great coal-producing regions are developing manufacturing centres with immense resources.

The Huge Possibility of Water Power and a Vision of the Electric Age

Norway has in her great waterfalls and mountain torrents the power of eight million horses. Recently a single power station at Rjukan increased its capacity from 30,000 to 250,000 horse power by spending merely £85,000 on a reservoir. The result of such development is that electricity is becoming much cheaper in Norway than steam power, and the Norwegians are swiftly building up a great industrial future. They use electric furnaces for smelting iron, and by means of electricity they manufacture large quantities of lime, soda, and ammonia—from the air!

This is, indeed, one of the strangest of recent discoveries. Having at last obtained control of Nature's mightiest force, man is now exploiting the air as well as the earth, and obtaining from it the substances he requires in his daily life.

But a still stranger thing comes into our vision of the electric age, for electricity is being used in a wider known but scarcely less wonderful way to transmit pictures over an ordinary telegraphic wire. A wave of light moves over a specially-prepared drawing, and in so doing sets up a series of electric impulses, which reproduce the picture on a drum fixed on a receiving apparatus. In this way photographs can be sent from Paris to London in a few minutes; and our picture shows how a scene in London might be reproduced in Edinburgh almost immediately by this remarkable invention.

The great Steel Man that Strides about the English Coast, Blasting away Rocks

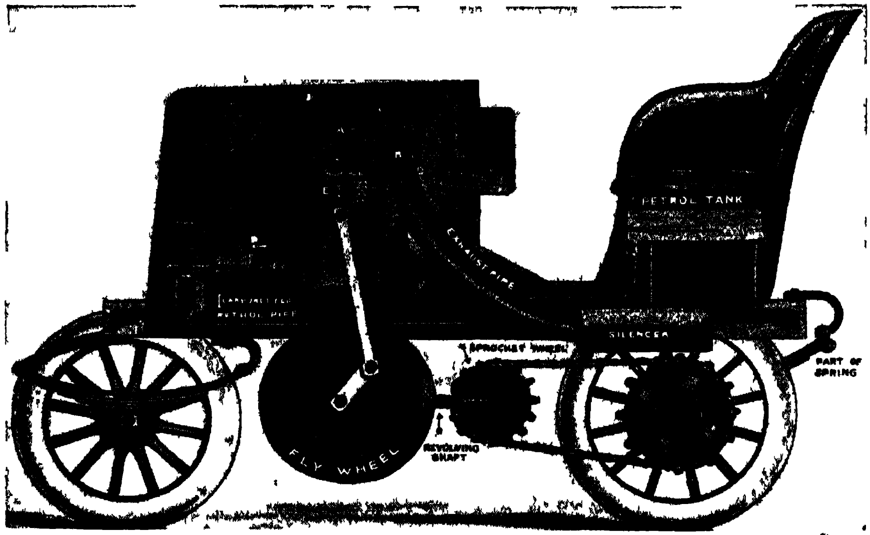
There would seem to be no limit to the use of electricity or to the sort of habitation in which this force may dwell.

A London firm of engineers has constructed something like the Martian Man of Mr. Wells's imagination. The Walking Man of Whitby—shown in a picture on another page—is an enormous machine, which is now striding about the English coast, building harbours and blasting away

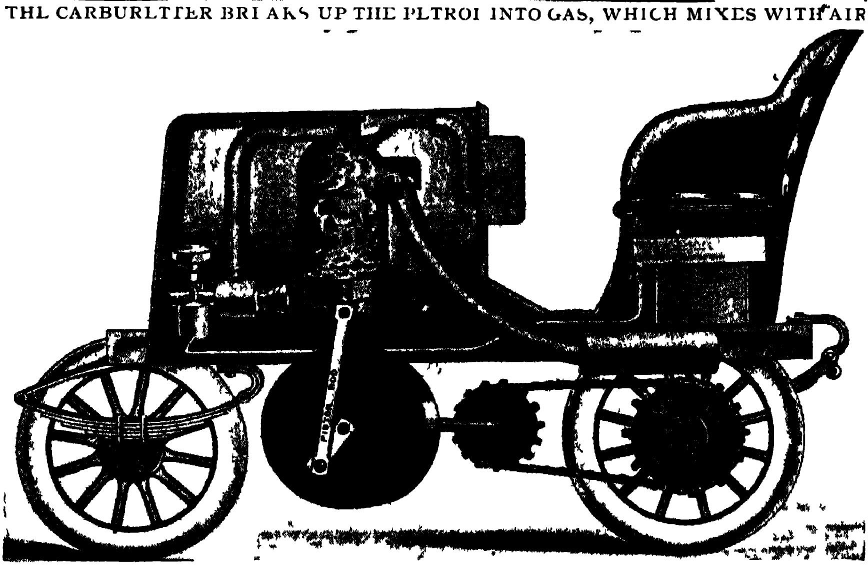
A MEETING & A CHALLENGE IN THE AIR

Well may we imagine the scene which our artist has depicted, where the condor, king of the air for ages before history, meets a man in the skies with a challenge which says "Who are you?"

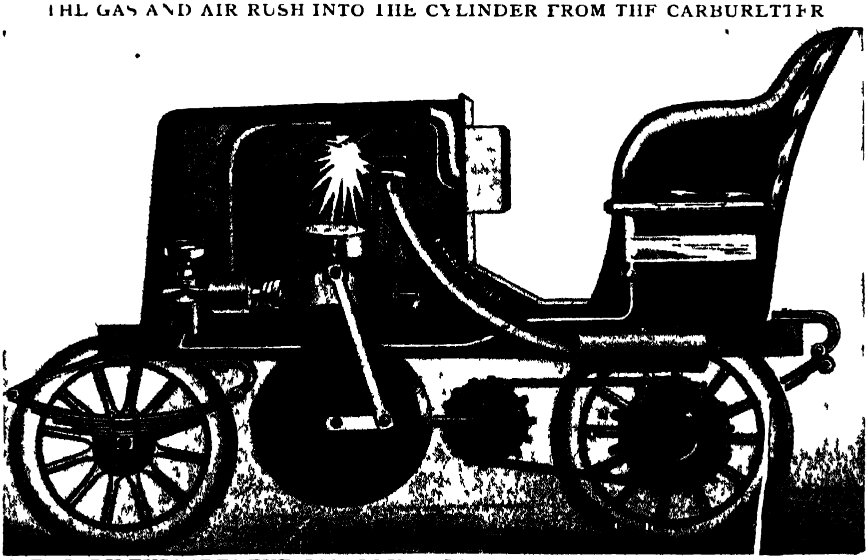
HOW PETROL MAKES THE MOTOR GO



THE CARBURETTER BREAKS UP THE PETROL INTO GAS, WHICH MIXES WITH AIR



THE GAS AND AIR RUSH INTO THE CYLINDER FROM THE CARBURETTER



THE SPARK EXPLODES THE GAS, DRIVES THE PISTON, AND TURNS THE WHEELS

SOMETHING like 10,000 things go to the making of a motor-car, and the way in which the complex parts work together as smoothly as a watch is perhaps the supreme achievement of the modern engineer These pictures show very roughly the main principles of the working of a motor car'

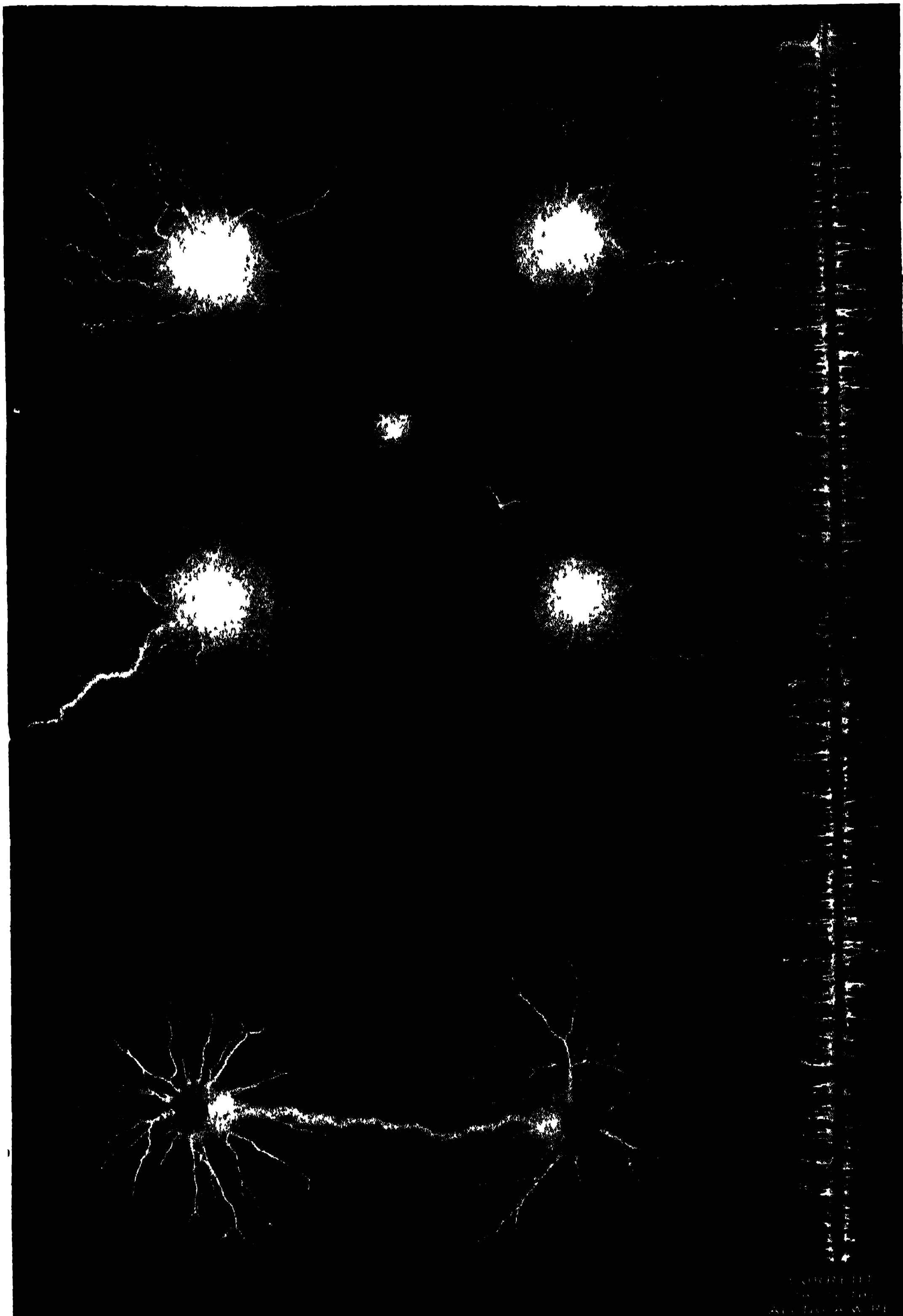
A is the inlet valve open ready for the gas to rush in B is the exhaust valve, which opens for the used up gas to rush out C is the sparking plug with its electric wires, which fire the petrol gas D is the current of air mixed with petrol going up to the inlet valve E is the piston attached to the fly wheel [This wheel is shown here the wrong way for the sake of clearness] The arrow on the piston cap shows the way the piston goes

When the engine is started, the petrol is forced from the tank under the seat, along the pipe into the carburetter shown in the first picture and here the petrol is sucked up through a small hole and mixing with air becomes gas This process begins with starting the engine by turning the crank in front of the car, which sets going all the machinery of the engine so that it continues automatically The fly wheel, which, of course, is turned by the first turn of the handle forces up the piston and compresses the gas into the smallest possible space, closing the inlet valve so that the gas cannot escape

The electric sparking plug is timed to spark at the instant when the gas is fully compressed and so causes an explosion The force of the explosion drives the piston down again, and so the fly wheel goes round, moving the road wheels, to which it is attached by a chain, though in most new cars the chain is now dispensed with

But another important work must be done in the cylinder before the car can go After the explosion the inlet valve closes automatically, and the exhaust valve (B) opens for the used up gas to escape The gas rushes down the exhaust pipe and out through the silencer, a box containing plates at different angles, which break the noise

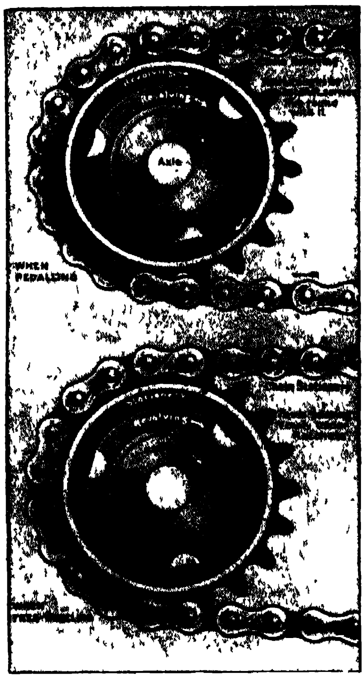
A PHOTOGRAPH OF AN ELECTRIC SPARK



These are some of the first photographs of electric sparks, about a thousand of which are made every minute in some motor-cars. This spark was fixed so that the flash fell exactly over a photographic plate, and what the eye sees as but a flash is shown to be in reality a thing of remarkable beauty.

rock to deepen channels for ships. It has eight legs, and when it is walking on loose ground it wears huge sand-shoes. The legs are worked by electricity, and so is the mighty crane with which it does its work. The steel monster weighs about 200 tons, and its legs are 37 feet long. It is so strong that it does not need to move out of the way of the blast of the dynamite cartridges which it uses on the rock beneath. The heaviest sea can break against it without disturbing it in its labour; it walks out and toils in rough water in Dover harbour when no ship could remain steady for a crane to be worked from it.

The conquering of space and time by electricity is one of the common facts of life, but a new invention, the railophone, bids fair to do astonishing things. The invention of a Birmingham engineer enables a passenger in the fastest train to talk with anyone on the telephone system. It may soon be possible to hold a conversation with a man in Astrachan while we are travelling through England on an express at sixty miles an hour. This, however, is not the most important thing about the railophone. It has a bearing on the development of the railway. Now that the monorail has become, by the use of the gyroscope, a practicable means of traffic, it is highly probable that we shall be able to speed from place to place at a hundred miles an hour, and one happy result of this will be the diffusion of our now overgrown cities.



THE FREE WHEEL OF A BICYCLE

When we pedal, the chain moves the toothed wheel round, and a number of notches inside catch against little movable half-discs, [illegible] pawls, ca[illegible] the hub of the bicycle wheel to rev[illegible] When we press on the pedal, howeve[illegible] he chain and toothed wheel stop moving [illegible]d the pawls slip over the notches, allow[illegible]ng the hub to go on revolving.

A slow railway is a centripetal force; it draws the best life of the countryside into a vast urban maelstrom. The social history of nearly all civilised peoples for the last sixty years is merely the history of an enormous swirl of population into a magic radius of three or four miles, to suffer there physical and moral disaster less apparently acute, but eventually more appalling to the imagination, than any pestilence that ever swept the world. A very rapid railway, on the other hand, is a centrifugal force. When mankind is able to travel, cheaply and safely, fifty miles in half an hour, the homes of rich and poor will again be set among green fields and wind-swept cliffs by the sea. The United Kingdom will be a garden kingdom. Factories, no doubt, will be scattered over it, but, being run by electricity, they will not spread soot and blight on the woods and meadows around.

One might naturally think that the great speed of travel necessary in bringing about this revolution would be attended with terrible danger. What would happen in the case of a collision? Well, the railophone makes collision on a railway impossible. Not only will every train be wirelessly connected with the telephone system, but each engine will be linked to all the signal-boxes that it passes; and every train will be in automatic communication with the trains nearing it. When two trains approach so closely as to be in the "danger zone," a wireless telephonic circuit will be set up automatically between them, and bells will ring to warn the engine-drivers to avoid collision. Moreover, a train which is overtaking another may be stopped dead by a brake action worked by the train in front of it; and any signalman can apply a brake to a train without regard to what the engine-driver is doing.

All these applications of electric power are so numerous, so important, so pregnant with larger results, that we are sometimes inclined to overlook the indirect uses of electricity. Chief among these is the new explosive engine which is becoming a prime mover of incomparable value. By employing an electric spark to ignite some vapourised oil or spirit, a novel and wonderful explosive engine has been invented. Set on four wheels, it becomes a motor-car, with a velocity of over eighty miles an hour; placed on a ship, it forms the "oiler," which is now in course of ousting from the seas the old-fashioned steamship; and, fitted with wings, it carries man high in the air, giving him the swiftness of flight and the range of power of the eagle.

TWENTY WAYS OF USING THE LEVER

The lever is one of the oldest and simplest mechanical devices, yet one of the most important. It enters into every machine and engine, and we cannot talk or walk or eat without using it. There are three orders of levers, as shown here, but every lever must have a rigid rod or frame, straight, as in a crowbar, or bent, as in pincers, and this must rest at some point on a pivot, called the fulcrum. Then any weight or force working at one point in the rod can always be overcome by force applied at another point. In the three orders the positions of fulcrum, weight, and power are different. On this page are examples of each form of lever, and some double levers, such as scissors and pincers.

It seems as though the aeroplane will prove more than a match for that other strange modern instrument of warfare—the submarine. A series of experiments were conducted at Cherbourg recently, in which some flying men fought a sham fight against two submarines. It was found that a man on an aeroplane could, from a height of 3,000 feet, see a submarine gliding eighteen feet below water, while the sailors in the submarine could not sight the aeroplane at a greater height than 1,500 feet.

The Coming of the New Oil Engine which will Revolutionise Life at Sea

Now, however, the men of science in the service of the American Navy have, it is reported, invented a new weapon to enable sailors and soldiers to fight against the terrible powers of the aviator. It is said that the American Navy possesses a gun which makes the aeroplane useless in warfare. The gun can be aimed and fired instantly, and it sends out a shell which bursts in the sky, showering explosives which spread out fanlike and destroy everything within a considerable range.

By that time, no doubt, the oil engine—at present one of the most exquisite mechanisms of movement—will in turn be made antiquated by something still smaller but more powerful. It is indeed already possible to divine what will take its place, for experiments are now being made in the invention of a new type of explosive engine. In the great petroleum engines used on large motor liners the electric spark is no longer required. The air, instead of being mixed with the oil in the process of vapourisation, is first compressed; the compression heats it to a very high temperature, and the crude oil is then sent to the cylinder, where the hot compressed air fires it, and the explosion takes place. By this means vessels of 6,500 tons are driven much better than they could be with steam. Oil takes up much less space than coal, the crew is much smaller, there is a great increase in the carrying capacity of the boat, and the terrible conditions of the depths of an ocean liner are for ever abolished.

Can the Power behind War be put into the Industries of Peace?

Even a petroleum tank, however, occupies a great deal of room. It may be much less in size than coal-bunkers, furnace-rooms, and boiler-rooms required in a steam-engine, but it is large enough to be very inconvenient on a motor-car or an aeroplane. What is needed is a far more highly compressed form of fuel than petrol or alcohol; and some French engineers are now trying to make a really explosive engine—one worked by the energy liberated by a stream of small, ignited particles of dynamite, nitro-gelatine, nitro-glycerine, or some other modern explosive substance. The two difficulties in the way are the formidable heightening of temperature produced by a single explosion, and the problem of getting varying and relatively moderate movements out of an abrupt and violent source of energy, but it is said that these obstacles can be overcome.

How glorious an achievement of the new spirit it would be if the chemist and the engineer, who have armed the nations with the terrible energy of modern explosive weapons, were to transform the power behind the artillery of war into a new force in the industries of peace! The invention of an actual explosive engine, by its concentration of fuel, would revolutionise every mode of travel; and if a cheap explosive material could also be found the end of the age of coal would be very near, with the abolition of the most primitive form of human labour now left to any considerable extent in the civilised world.

The Astonishing Things that are Done in Laboratories To-day

We have been thinking mostly of the physicist and the inventor and the engineer, but it may be said that the modern chemist is in many respects the supreme magician of our day. He has revived the idea of his ancient predecessor, the alchemist, and shown by actual experiment that the strange dream of the transmutation of the elements was a sober truth. It is to him that we owe the marvellous X-rays and the still more marvellous radium; and of late he has given us a new element, neon, from which comes a light superior to the radiance of gas and the glow of electricity, and almost equal to clear, soft, steady daylight. He has also discovered for us the wonderful curative rays which are being applied with success in the treatment of disease.

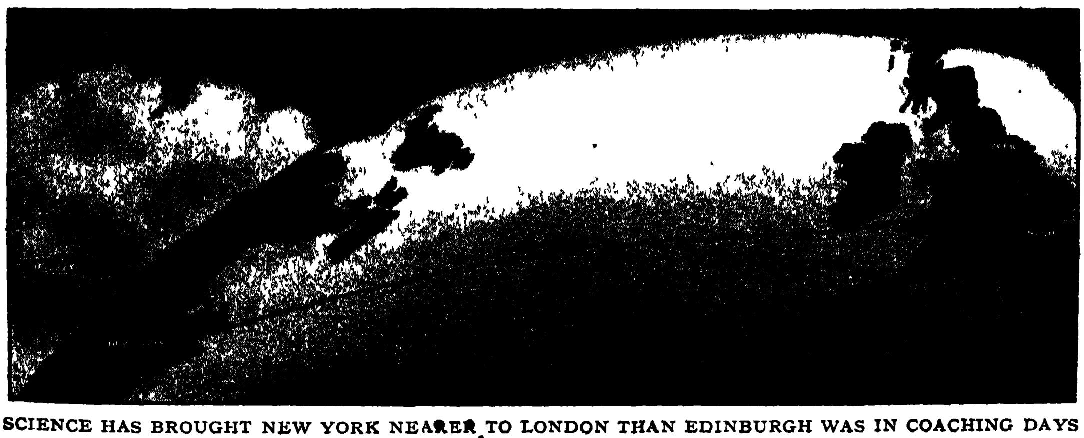
It is remarkable, indeed, what power has been recently derived from modern chemistry. In his laboratories to-day man can manufacture substances which he was once compelled to extract from living things. He has recently split up the atom, has seen into this invisible thing, and mapped it out as a system of intricate forces more marvellous in structure and movement than the solar system. At last the chemist has analysed every element of the material

THREE KINDS OF POWER IN THE COUNTRYSIDE—HUMAN POWER, ANIMAL POWER, AND WIND POWER

world into combinations of electrical force. To him the universe is made up of two things: centres of electrical force, and a subtle, intangible, all-pervading ether, apparently not subject to gravitation.

Here we come to the ultimate problem in science. Will man ever control the mysterious force which holds in silent equilibrium the solar system on one hand and the mighty powers in the infinitesimal atom on the other? If we could set loose the immense store of electricity contained in a small pebble we should get an inexhaustible source of power, such as would make us, perhaps, the virtual masters of the universe. It is the last dream of science, and who shall say yet that it is in vain? The wonderful new knowledge of to-day is the growth of only two or three hundred years. The human race is still young. All calculations of the duration of the sun and the life of the earth have been completely upset by the finding of radium. The length of time during which the earth will support life is now beyond all estimate. Food will always be abundant, and so will the sources of energy. With so large and firm a foundation, man will surely continue to advance.

Yet there is still one rock on which he may founder. When man has conquered Nature, he will be faced with the harder task of conquering himself. Many a nation has been vanquished by its own victories; it has won the means of luxurious life, and then, giving itself up to self-indulgence, has lost at last the manliness of character, the singleness of mind, and the strength of soul which it possessed in the days before it set out on its conquest. In the last analysis, the question of the long future of the human race is a social and religious problem. If it can retain, amid all its triumphs, the spirit of self-sacrifice, the brotherly love, the humility of mind, and the wholesomeness of heart inculcated by the greatest religious teachers, then it may survive when the sun is a cinder and the earth as we know it no longer exists.



SCIENCE HAS BROUGHT NEW YORK NEARER TO LONDON THAN EDINBURGH WAS IN COACHING DAYS

THE PENT-UP ENERGY OF AGES & AGES

It often happens that oil shoots out of the earth with tremendous force, driven out by the gas which has been pent up with it for thousands of years, and millions of gallons run to waste in this way. Men with leather suits and metal helmets fix steel caps over these gushers when at last they can be controlled.

LIFE IN THE GREAT OIL-FIELDS

The Universal Power Pent up for Ages and Ages down in the Depths of the Earth

THE MINERAL OF THE MODERN WORLD

We can easily picture what the world was like before railways. Many of us can quite well remember the days before the electric light and the telephone. A world without electricity at all is not very hard to imagine; but a world without mineral oil, without petroleum—try to imagine that!

Perhaps you think this is not so difficult. In that case you have clearly no conception of the many uses to which petroleum is put. Only a small quantity of the whole production is employed to give light. Abolish mineral-oil lamps, and the petroleum mining industry would go on almost as vigorously as it does now.

Petroleum would still be used for making gas, for making paraffin-wax candles, for making electric-light carbons. It would still be necessary, in the form of lubricating oils, for keeping in order the machinery upon which the modern world depends. It would still be the motive power for motor-cars, gasoline engines, and flying-machines.

It is petroleum which has made flying possible. No form of motive power but the petrol engine was light enough to be carried in the air. Here is its greatest achievement. At the other end of the scale of utility it supplies us with perfumes and cosmetics. In between come a multitude of uses. It gives us asphalt paving, permanent ink for printing, dyes of brilliant hue. It gives us aluminium, the production of which depends upon petroleum. It gives us tennis-balls, rubber tyres, all kinds of rubber articles which, without petroleum, could not be manufactured.

Strange, then, seeing how much use we all make of petroleum and its products in our daily lives, that it is only just over half a century since this mysterious oil began to be extracted in any large quantity from the bowels of the earth, where it is formed, in all probability, out of decaying animal and vegetable remains. In 1859 the first well in the United States was drilled by Colonel Drake. Up to that time mineral oil had been collected by means more or less casual. Thenceforward the mining of petroleum became a science. It also became one of the largest industries in the world.

Very soon the regions where oil was known to exist began to be "prospected." In some places shepherds had been in the habit of driving their flocks to pools of oil, and lighting the oil for warmth. In the Caucasus there was a Parsee shrine where a flame had been alight since before the birth of Jesus. It was a place of pilgrimage for fire-worshippers. In Galicia and Roumania old books told where oil had been taken out of the earth for centuries. The great mineral of the modern world had been tapped by men who could not have had any conception of its power.

The principal oil-fields from which the world draws its supply of petroleum are in the United States, Russia, Roumania, Austria-Hungary, East Indian Islands, and Burma. Other countries where deposits are being worked are Mexico, Peru, Assam, Japan, Germany, the West Indies, and Persia. When the known deposits are exhausted, there will remain immense areas yet untouched where oil certainly exists; so that there is no likelihood of the supply of petroleum failing for many centuries to come. The amount at present taken out of the earth is nearly a million tons a week.

It was not known at first that petroleum could be used for lighting. Upon the discovery of this followed hard its employment in other ways. The practical business minds of the United States set to work to make the most of the addition to the

wealth of the country. Scientific men also contributed to the development of the industry. Several famous chemists devoted themselves to the study of petroleum, among them Mendelieff, Sir Boverton Redwood, Lissenko, Engler, Beilstein. They are not yet agreed as to its precise origin. Mendelieff, for instance, thinks that it was formed by the action of water on molten or heated metallic carbides. Engler maintains that it must be due to the liquefaction of animal remains: he has actually exhibited products, exactly similar to those of petroleum, which he had made from animal fats. Another chemist, named Warren, has found the substances extracted from petroleum in a liquid form by distilling vegetable matter.

Equally valuable, and perhaps of more immediate practical use, has been the work of the geologists who have studied the formation of oil-fields. This branch of knowledge is still far from complete, but enough is known to prove of great assistance to prospectors. It is now accepted, for example, that petroleum is always found in a series of "fields," which are really natural underground tanks or percolations, and that these fields always run parallel to a mountain range.

A Discovery that has Made Fresh Openings for Men of Brains

The mountain ranges are not always to be found to-day. They have doubtless in many cases disappeared. But even if indications of their position can be traced, the petroleum mining engineer knows where the deposits are to be looked for.

Thus, while the discovery of petroleum as an industrial product has given the poor, who before could scarcely ever afford to use artificial light in their homes, a cheap and bright illuminant, and while it has at the same time provided the world with a new motive power, it has also brought into being new activities of science, and offered fresh openings to men of ability and brains. "There are few branches of engineering," says Mr. A. Beeby Thompson in his text-book on the subject with which he is so thoroughly well acquainted, "that offer brighter prospects to an energetic and enterprising engineer, and there is certainly none that presents more varied and interesting problems."

A vast amount of capital is employed in oil-mining, and in recent years oil has shared with rubber the most frenzied attention of Stock Exchange speculators. This has done the industry no good. Money for development has been attracted, but the floating of doubtful companies has disgusted many of the "sound investor" class, and it is this class alone which lends to any enterprise solidity and strength. However, at the time when this work is issued, the market shows a tendency to become steadier; and no doubt petroleum-mining will soon settle down.

A Vast Business which may yet be only at its Beginning

There is undoubtedly money to be made by legitimate investment, for the consumption of petroleum and its products is increasing, and seems likely to continue to increase, especially when liquid fuel comes more generally in use. There are many, indeed, who think we are only at the beginning of the industry even now.

Here are some figures showing the enormous increase in the production of petroleum during the last forty years:

	metric tons		metric tons
1878 ..	2,077,291	1898 ..	16,381,060
1881 ..	6,833,204	1908 ..	38,052,000

During the 'eighties and 'nineties the United States and Russia kept fairly level in their output. During this century the American oil-fields have increased their production very largely and left the Russian oil-fields far behind. Meanwhile, Roumania and Galicia are gradually creeping up, though their quantities are trifling compared with those of the two great oil-producing countries.

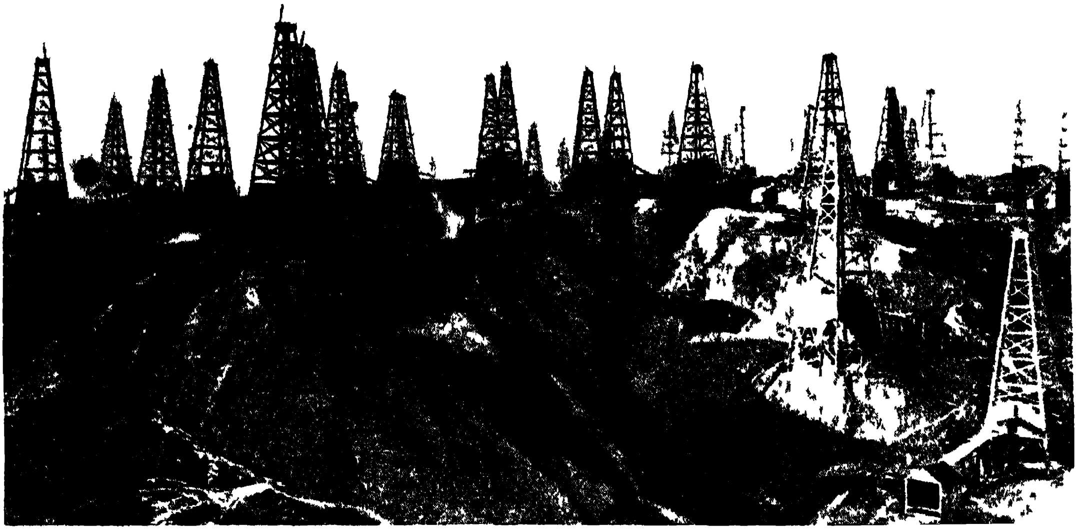
Let us pay a visit to an oil-field. We will choose the most famous on this side of the Atlantic, the oil-field of Baku, in the Caucasus. From London we take a direct ticket, and for the first stage of our journey go to Moscow. That is nearly two and a half days' journey, and yet from Moscow we have more than as long to go again. Leave Moscow on a Saturday afternoon and you get to Baku on Tuesday morning.

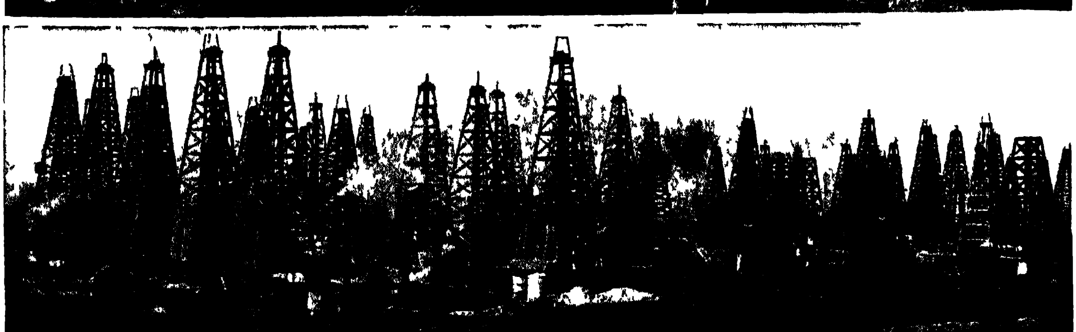
Like a Forest Blackened and Charred by Fire

It is an interesting journey, though, first across the flat interminable steppes, then into the mountains. The snowy peaks of the Caucasus gleam far off in the hot sunshine. The people of the Caucasian races crowd the railway-stations, in their sheepskin hats and long coats. One sees mosques as well as churches, for they are mostly Mohammedans here. And all the time we are passing at frequent intervals long trains of oil-reservoirs making their way north.

At first sight an oil-field looks like a forest blackened and charred by fire.

WHAT THE OIL-FIELDS LOOK LIKE



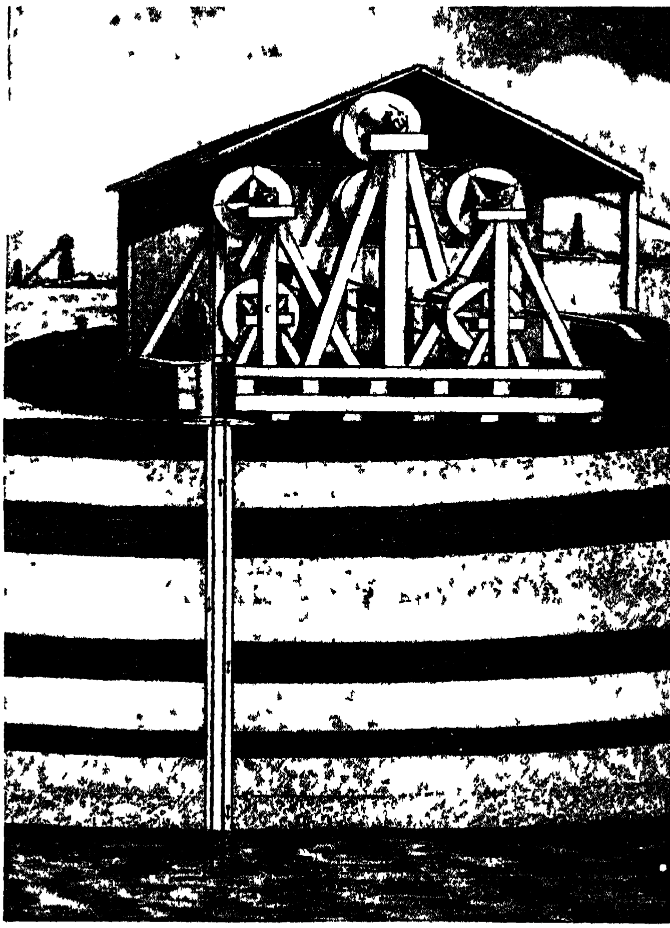


At first sight an oil-field looks like a forest blackened and charred by fire. Above every well is an erection called a derrick, something like an hop-oast in shape, and mostly of a black and dilapidated appearance, though sound enough to support the strain of the huge tools let down into the well

Above every well is an erection called a derrick. It is something like a gigantic hop-oast in shape. These are mostly of a black and dilapidated appearance. They are sound enough in reality, or they would not support the strain of the huge tools and "balers" that are let down into the wells. But they look very hideous and ruined when seen from a distance.

Nor is this first impression of dirt and dreariness wiped out on closer inspection. Among the derricks there are mud pools everywhere — slimy, viscous, horrible. Masses of iron piping lie about; heaps of spare implements. There are no roads, only tracks. Take care that you do not step into an oil pond or trip over a pipe-line.

We stop for a few minutes at the door of a derrick. They are hauling up a drill with which they have been deepening the well. One of the workmen says something in Tartar, and motions us to stand back. Too late! Out comes the drill with a sputter of oily mud all over us.



THE ENDLESS BAND THAT BRINGS UP OIL

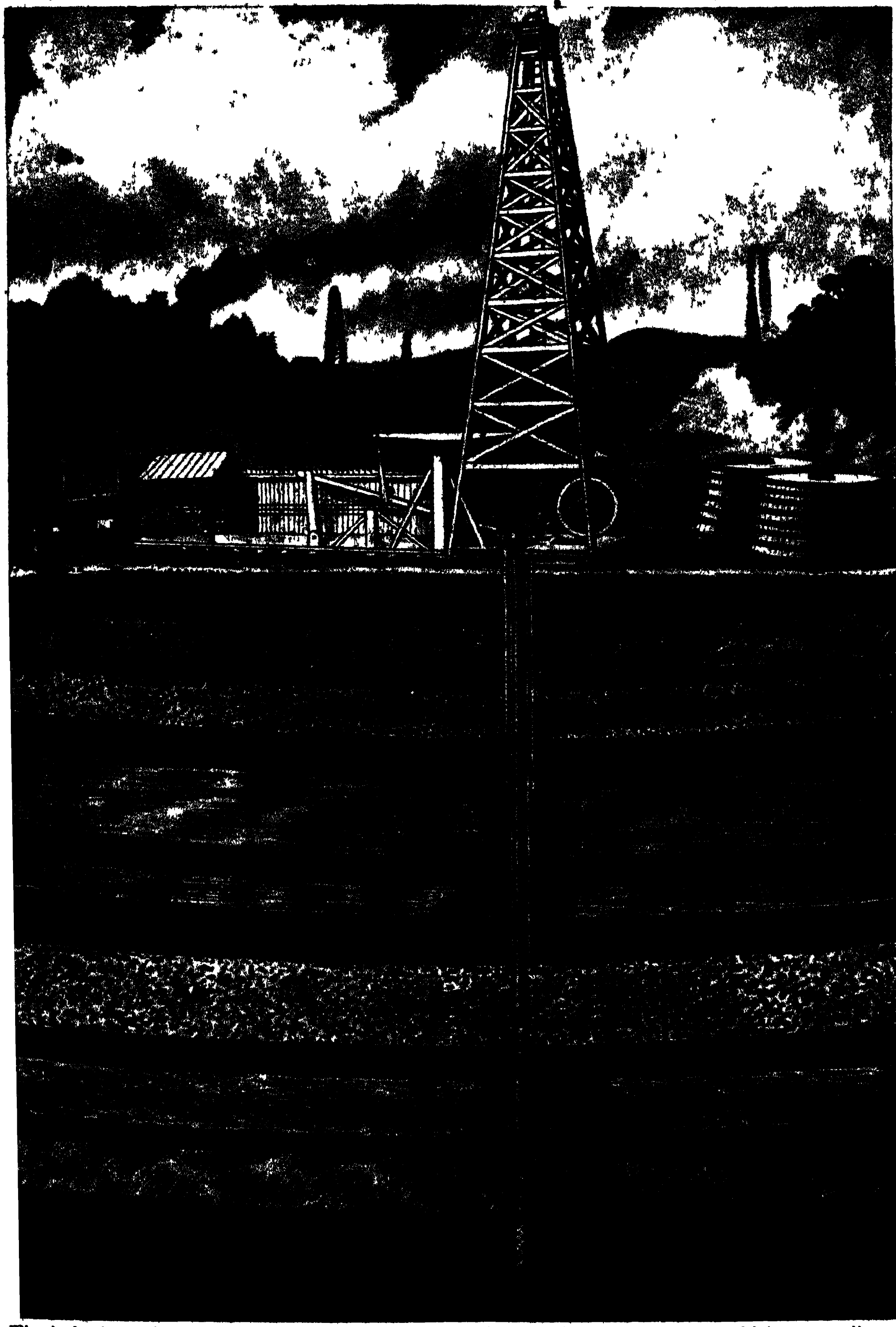
An endless band is one of the newest ways of bringing oil to the surface, though it is not widely used. The band is sent down into the well, where it is soaked in oil, which it gives off on reaching the top, where it is squeezed between rollers.

The first thing to do when the existence of oil has been discovered is to make a hole through which it can be got out. The hole is made first with instruments called "spuds," and finished with powerful drills. As the shaft is sunk it is cased in with iron tubes, which are let down from the top. As the work proceeds smaller tubes are placed inside the first ones, and smaller drills are used. Then the space between the tubes must be filled up. Every care has to be taken to keep the sides of the well solid and water-tight. When the oil is drawn up mixed with any considerable quantity of water, its value is very much diminished. Oil and water must be separated, and the cost of production is thereby largely increased.

By a cable from two to two-and-a-half inches in diameter a string of tools is lowered into the well. These tools are screwed together with a great deal of force, so that no blows in the well shall cause them to come apart. When tools are lost in a well they have to be fished for. Special "grabs" and "spears" have been invented for this purpose, but it is often a long time before missing implements can be found. Sometimes an impression has to be taken of the bottom and sides of the well to discover where they are.

The drill falls at the rate of from twenty to forty strokes a minute, according to the nature of the soil. Now they are stopping it. It is hauled up, and a cleaner is substituted for it, to take out the pulverised earth. The cleaner has on its lower end a valve that opens inwards and allows the debris to enter. When it is full, the valve automatically closes and the cleaner goes up to be emptied. When there is a great deal of sand or thick stuff in the well, a "sand-pump" is used. This is a cleaner with a piston inside it, drawing up through the valve the stuff which is not light and loose enough to enter freely.

HOW OIL COMES UP FROM THE EARTH



The hole through which oil comes up from the earth is cased in with iron tubes, which are smaller as they reach the bottom; and through this iron shaft, which may be anything from 1000 to 2500 feet deep, the oil is brought up in various ways. This picture shows the usual way of bringing up oil, by pumping.

THE TERROR OF FIRE IN AN OIL-FIELD

The sight of an oil-field with a spouter alight, with derricks burning and brooks of oil carrying hither and thither sheets of flame, with vast volumes of black smoke darkening the sky, might well inspire an artist with the imagination of a Gustave Doré to paint a picture of the end of the world. The best

LIKE A SCENE OF THE END OF A WORLD

way of putting out such a fire is to inject steam into it, and this is often done. Other ways of extinguishing these fires are to drag an enormous weight of steel rods over them, or to run an enormous iron cap along the rails, dropping the cap over the flame as a snuffer is dropped over a candle.

The well having been sunk to the required depth, which may be anything from 1,000 up to 2,500 feet, the next proceeding is to get the oil out. There are various ways of doing this. The most usual in the United States is pumping. Where this is possible, it is the cheapest and most efficient. The oil, when pumped up to the surface, is received in a reservoir or carried off by a pipe-line to some central storage tank. That is simple enough.

The Men who Bring Up the Huge Baler that Dips Down into the Well

There are some oil-fields, however, where so much sand comes up with the oil that pumps cannot raise it. Then valves and plungers are soon put out of action. Here the oil is got up by means of a "baler," a huge tube fifty or sixty feet long. This is lowered into the well. It is filled by the action of a valve opening inwards, as in the cleaner; and then it is hauled up and the oil is discharged into a "baling tub" where the sand is allowed to settle before the oil goes into the tank. There is a fascination in watching the huge "baler" shoot up out of the well. Come in and see it. There are only three or four men in the derrick. The foreman is an Armenian, bright-eyed, intelligent. The rest are Tartars, hook-nosed, high-cheek-boned. One has his beard dyed—no, not dyed: it is actually painted. Grey hair is considered unlucky among the Tartars, and this is an oldish man. The "baler" is going down now. You can just see the wire rope spinning away down into the well. Now the man at the engine puts in his reverse. The rope slips upward, up, and up, and up, coiling itself on a drum high above us. Will it never be done?

The Marvellous Bucket which Brings Up 100,000 Gallons of Oil in a Day and a Night

Suddenly — swish! ploop! the baler shoots up out of the deep hole. You step back instinctively. It is so large after the thin wire. Showers of oil are dropping from it. The whole place is filled with its sputter and splash. Only for a few moments it stops, just long enough to run out its 275 gallons of oil, then down it goes again. Day and night it works. Something like 5,000 gallons an hour it brings up from 2,000 feet below the surface. Only three or four workmen look after it; it is another marvel of the Machinery Age.

Near by, though, is something even more marvellous. Here there is a continuous flow of oil into a tank outside a derrick, with nothing to show how it is being brought up. There is no wire, no one about, no visible agency. All that we see are a couple of pipes, one going down, the other coming up out of the well. Now, the pipe that goes down is charged with compressed air. This compressed air forces the oil up the other pipe, and so into the tank. It is quite simple, after all.

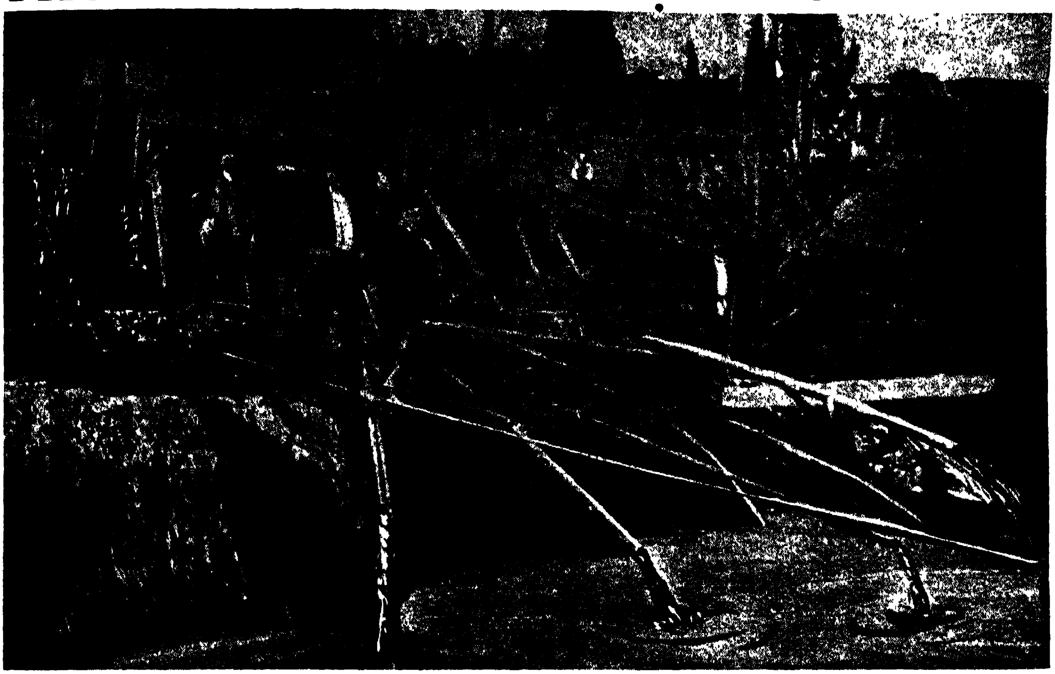
There is a point to notice about that compressed air before we leave it. It is compressed by gas-engines, which are fed by the gas from the wells. Wherever petroleum is, there is also natural gas. A great deal of it is wasted—most of it, in fact— but here it is being made use of. It is sucked out of the wells into gasometers, thence it is fed to motors and also to the boiler-houses, which provide the power for the well engines. See what clean, clear, roaring fires it makes! Some of them are oil-fires. In time oil-fuel may perhaps supersede coal altogether. No more filthy stoking in a scarcely endurable atmosphere! No more gangs of half-naked shovellers, dripping and gasping in the stoke-holds! Only a mechanic or two, clean and cool, turning a tap every now and then to regulate the spray of oil which feeds the blaze.

The Escape of the Gas Pent up for Hundreds of Thousands of Years

Another method of raising the oil from the wells is the air-lift process. This is quite distinct from the compressed air plan. It does not force the oil up, but, by aerating it, causes it to flow gently in a constant stream to the surface. A fifth system has in the last few years been invented by an Austrian engineer. This sends down into the well a specially-made endless band, which aerates the oil. When it comes to the surface it is squeezed between rollers, the oil drops off into a conduit, and the band pursues its way downwards to be passed through the oil again.

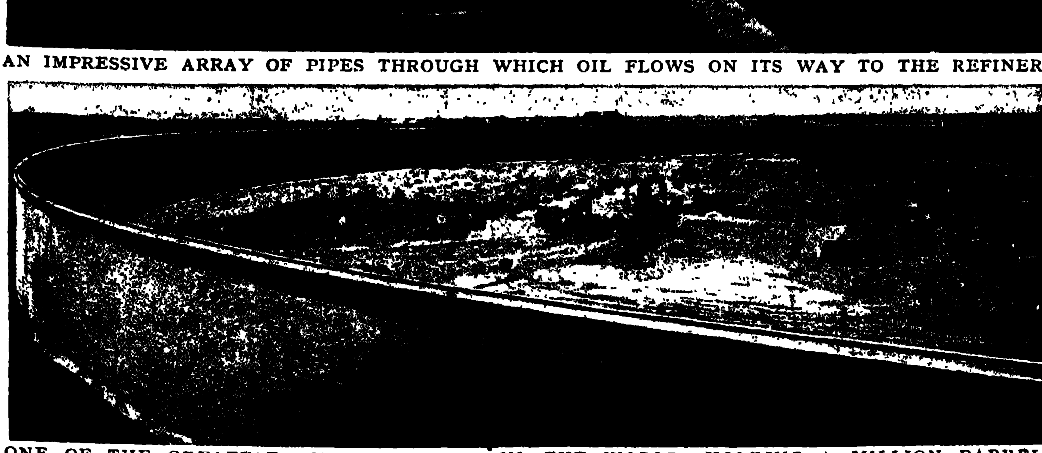
All these methods are for use when the flow of oil has been got well under control. It often happens that at first the oil shoots out of the earth with tremendous force of its own accord; or, rather, it is forced out by the gas which has been pent up with it for hundreds of thousands of years, perhaps. In these cases, as soon as the drill pierces the oil deposit, there is an upward rush, and, unless precautions have been taken to control it, enormous quantities of oil are wasted. These rushes of oil are called "spouters" or "gushers." They rise to a great height, and, if one is watching them, it is necessary also to watch the wind, and to keep carefully to windward of the oil.

THE PIPES THROUGH WHICH OIL RUNS

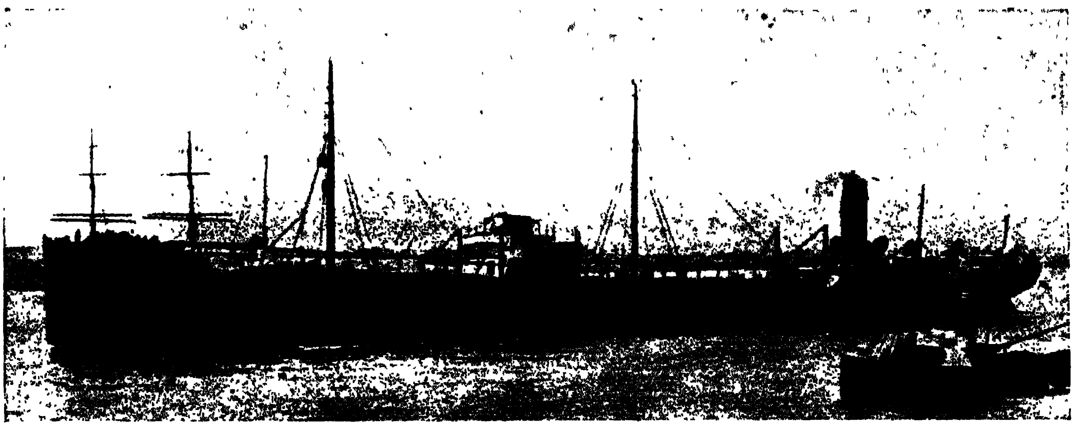


AN OVERFLOW OF OIL RUNNING INTO A ROUGH NATURAL RESERVOIR AT MORENI, ROUMANIA

AN IMPRESSIVE ARRAY OF PIPES THROUGH WHICH OIL FLOWS ON ITS WAY TO THE REFINERY



ONE OF THE GREATEST OIL RESERVOIRS IN THE WORLD, HOLDING A MILLION BARRELS



THE TANK OIL STEAMER, OFTEN CARRYING A BURDEN OF SIX THOUSAND TONS ACROSS THE SEA

Sometimes a gusher continues a long time. One at Baku lasted eighteen months. This was not a violent flow expelled by gas, however. It was steady, and the cause of it was the dissolution in the petroleum of gaseous hydro-carbons. These reduced the weight of the column of liquid—having the same effect, in fact, as the aeration—and accounted for the discharge. At Grosny, in the Caucasus, an unfortunate Englishman struck a spouter, and thought he had made his fortune. But he could not control it. The oil ran away down-hill. It killed sheep and spoilt pasturage, and farmers began putting in claims for compensation. The owner of the spouter would have paid handsomely for the flow of oil to be stopped, but nothing could stop it, and he was ruined.

The usual method of controlling a powerful discharge of oil is to have a "casing head" at the top of the well, fitted with strong valves, through which the oil can be led away into a reservoir. But it often happens that the discharge is too violent to be tamed in this way, especially when there is much sand with the oil. Even a pressure of 500 lb. to a square inch has failed to keep a gusher down. Cast iron or steel valves have been cut to pieces. Casings have been burst asunder by the tremendous force of the oil. In many Caucasian oil-fields it is usual to fix a heavy steel or cast iron shield about eighteen or twenty feet above the mouth of the well, to prevent the column of oil from being blown about, and so lost. Even these shields have been utterly destroyed, however, by the stones and sand shot up with the petroleum.

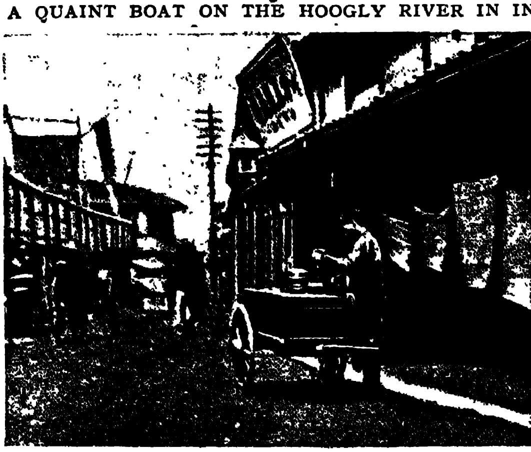
A great danger when a spouter has been struck is the possibility of its catching fire. The sight of an oil-field with a spouter alight, with other derricks burning and brooks of oil carrying hither and thither sheets of flame, with vast volumes of black smoke darkening the sky, might well inspire an artist with the imagination of a Wiertz or a Gustave Doré to paint a picture of the end of the world. The best way of putting such a fire out is to inject steam into it. A number of pipes are each coupled to a high-pressure boiler, and at a given moment they are all turned on to

THE OIL-TRAIN, SHOWING THE PIPES FROM WHICH THE TANKS ARE FILLED

The reproduction of some of the photographs in these pages is by courtesy of the Anglo-American Oil Company and the Oil Well Supply Company

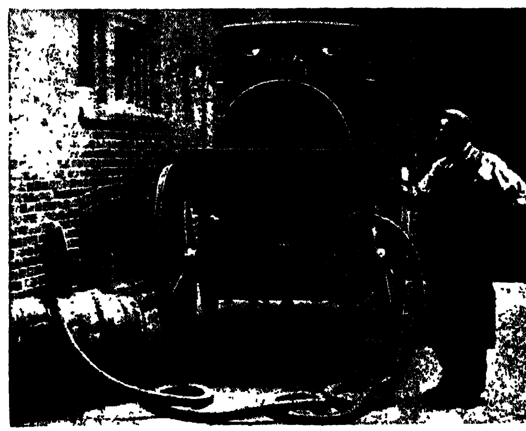
THE OIL ON ITS WAY ROUND THE WORLD

A QUAINT BOAT ON THE HOOGLY RIVER IN INDIA, WITH OIL FOR THE CITIES ON THE GANGES



THE MOST PRIMITIVE FORM OF DISTRIBUTION

Filling a lamp direct from the cart in Japan.



THE MOST MODERN FORM OF DISTRIBUTION

Pumping oil from a street tank in England.

DONKEY CARAVANS CARRYING OIL FROM THE SEAPORTS TO THE TOWNS OF NORTH AFRICA

It is hard to think of a world without oil, almost the only mineral product which finds its way to every corner of the earth. These pictures show some of the ways in which the oil reaches its destination.

the flame. The steam prevents air from getting to it, and without air it dies.

Now we have seen how the oil is extracted from the bowels of the earth. But, as it comes up, it is fit for very few uses. Almost all of it has to go through the process of being refined before it is good for anything at all. According as it is refined, it becomes lamp oil, lubricating oil, or liquid fuel. It goes into the refinery a thick, brown, sludgy substance, oozing along, and smelling strongly of gas. It may come out perfectly white and almost odourless. That is the most highly refined product. From that downwards we have a scale of oils until we come to the residue, which is the thick stuff used for liquid fuel.

The Oil that Lights Up the Home and Darkens the Face of the Earth

An oil-field is not a pleasant place, as we have seen. It is exceedingly interesting to visit, but one would not choose to spend a holiday there. Still less, however, would one care to pass any more time than one can help in an oil-refinery. At Baku they call the quarter where the big refineries are Black Town. It would be impossible to find a better name. Everything is black—roads, walls, chimneys. Columns of smoke do their best to blacken even the sky. As we go into New York Harbour we see far away over to our left, on a spit of land, the chimneys of the Standard Oil Refineries, making a dirty patch upon the blue horizon. There seems to be something in the nature of the industry which causes it to form blots upon the fair surface of the world, wherever it is carried on.

When on a winter evening the cheerful lamps are lit, diffusing their clean, bright glow, and bringing light into dark corners, we must often think, if we have seen the places where the oil for the lamps is obtained and prepared, of the contrast between those places and the effect produced by their finished product. It is the same contrast as that between the stuff a gardener puts down to fertilise his plants and the exquisite flowers which spring from it.

The Oil Leaves the Refinery and is Ready for the Market

All the same, notwithstanding its depressing ugliness and filth, an oil-refinery is full of interest for the inquiring mind. Look at that row of stills, for instance. Nothing much of an appearance, certainly; but in those stills the process of refining the oil is at work. This is the way of it. First the oil is super-heated, then it passes through an instrument called a "deflegmator." Its various components are separated. It is turned into vapour, then it is condensed back again into liquid. The stills vary in heat. At first only oils of low density are formed. As the temperature rises, denser distillates are expelled and condensed. So from one process quite a number of different oils are produced.

In a shed close by there are many taps and tanks. Here the different oils flow. Now one can see the variations of colour and smell; but the oils are not yet ready for use. They have to be treated still further, first with sulphuric acid, and next with caustic soda. The sulphuric acid absorbs the constituents of the oil which contaminate it, but at the same time leaves a good deal of acidity in it. The caustic soda removes that acidity, and further cleans the oil. Then it passes into a settling tank, after which it is ready for market.

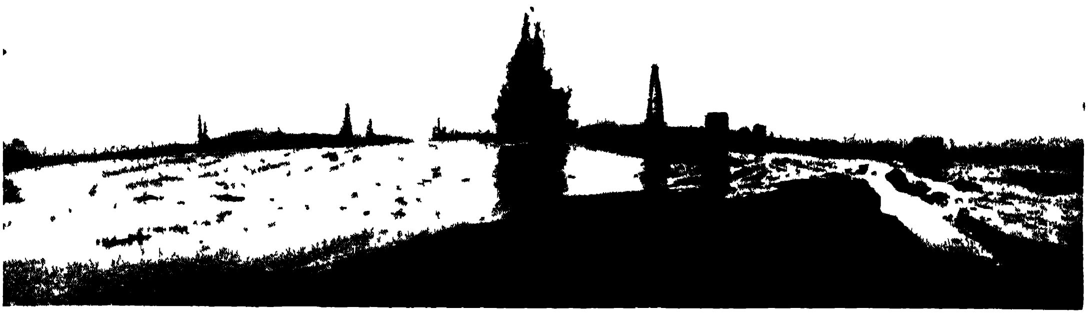
As a rule, however, the market is a very long way off, and difficult to get at. Oil is an awkward commodity to handle, and it must be handled in large quantities. It was the cost and the inconvenience of sending it in barrels over bad roads on waggons which made American oil-miners think of passing it through pipes.

The Distribution of the Oil to All Parts of the World

The first pipe-line was made in 1865, and ten years more passed before a trunk line was laid down, in Pennsylvania.

Now pipe-lines are common. There is one 500 miles in length, from Baku to Batoum. Another has been made from Maikop to Ekaterinodar, and there is one in course of construction from Maikop to Touapsé, the new port on the Black Sea, which is being developed solely for the traffic in oil. In Burma it has even been found cheaper to lay a pipe-line than to transport oil in barges down the Irrawaddy River.

Of course, these pipe-lines need to be laid with great skill and care. There must be no weak places where leakages may occur. The pumping stations must be well equipped and kept in good order. It used to be necessary, too, to guard lines against the attacks of carters who had lost the carrying of the oil. It was difficult not to feel some sympathy with them, as with all workers who suffer through ingenious machinery doing their work; but against the hardship to a few must be set off the benefit to the many who could buy their oil at a smaller price as the result of cheap and quick conveyance.



AN OIL-WELL WHICH FORMED A LAKE, THE STREAM ON THE RIGHT BEING ONE OF A DOZEN

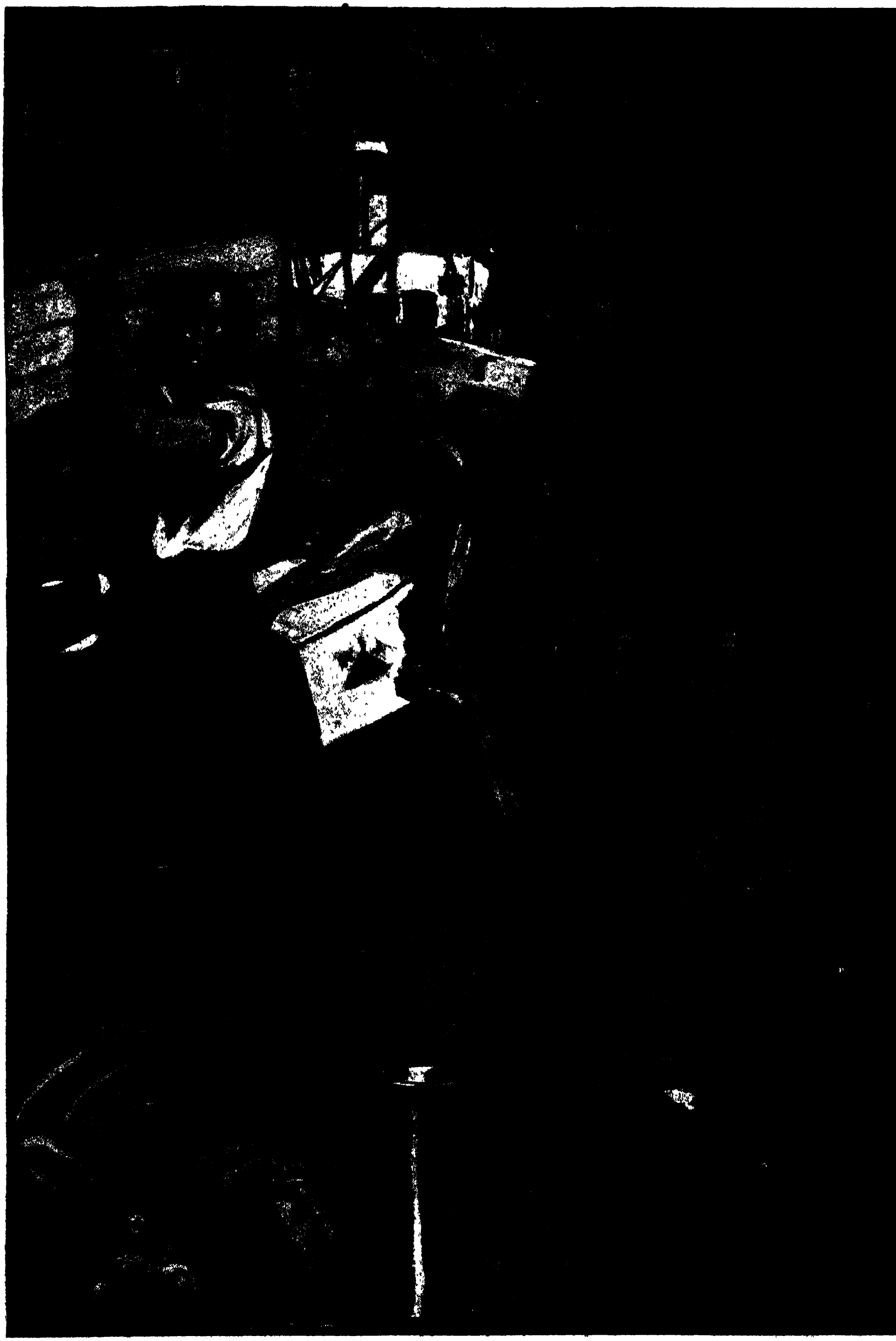
Another change of equal importance was made when the practice of shipping petroleum in barrels was given up. This was both clumsy and expensive. It occupied a great deal of labour, and the barrels often cost more than the oil they contained. Some other means of transit had therefore to be devised, and the invention which superseded barrelling was the tank steamer. The first was used on the Caspian Sea to carry the oil from the Baku fields over to the mouth of the Volga. Soon ocean steamers were built which could be filled direct from pipes, and now tank-ships are to be met with on all seas. They run up to six and seven thousand tons burden, and can steam as fast as eleven knots.

All over the world they carry petroleum and its many products. We know it under many names. Kerosene, paraffin, benzine, petrol, are among the most familiar. It is used to pour on stagnant water in malarial districts, so that the mosquitoes which carry the disease may be wiped out. It is put down on roads to prevent dust. It is thrown on to stormy seas so that the waves may be calmed and vessels saved from destruction. In millions of homes it provides the only artificial light, a cheaper and brighter light than was ever available before. It is banishing the horse from city streets a merciful release for the poor animals—since without it motors could never have developed to their present stage. It has made it possible for men to leave the ground and travel in the air.

The Egyptians used petroleum ages before the Roman Empire. The Aztecs of Mexico and the Incas of Peru were familiar with it. The Red Indians and the Persians used it for its healing virtues before they ever dreamed that white men lived upon the earth. In China and Japan mineral oil deposits have been worked crudely from time immemorial. But it has been left to this age in which we live to discover the numberless uses and properties of this gift of Nature, which has been made to add so largely to the comfort and convenience of the life of the world.

THE TERRIBLE SPECTACLE OF AN OIL-SHIP ON FIRE, SOMETIMES VISIBLE 35 MILES AWAY

ALL THE WORLD BUYS AND SELLS



All nations meet at the London Docks. Here we come into the world's market-place, where Persia is selling rugs, and India is selling jute, and Germany is selling dyes, and China is selling beautiful carvings.

THE CREATOR OF WEALTH

The Vast Business between Nations upon which the Prosperity of our Islands Depends

HOW THE WORLD GOES TO MARKET

COMMERCE, the interchange of commodities, is the handmaid of civilisation. The science of commerce is the science of the distribution of the world's products among the world's peoples. Upon the effectiveness of the interchange the wealth of the world largely depends.

Wealth may be defined as matter in the right place, as dirt has been defined as matter in the wrong place; and it is the supreme function of commerce to create wealth by moving commodities from the places where they can be easily produced, but where often they are useless or of limited use, to places where they cannot be so easily produced, but where they are needed. The progress of mankind—the progress of civilisation—may be measured by the progress of commerce. The sixteen hundred million people of the world possess most of the wealth they enjoy by virtue of commerce, and in so far as their condition is still poor and unsatisfactory it is because of the imperfections of commerce as it is.

But can commerce, or the mere interchange of commodities as between people in the same country, or as between people in different countries, actually create or increase wealth? It is important that we should not beg this question, but that, by framing a clear answer to it, we should gain a proper conception of the true importance of commerce as a science, and of the importance of purging commerce of everything that is unworthy or inefficient, in order that man may reap, from the little revolving globe upon which he is confined, the greatest possible material abundance.

In the first place, man gains wealth by commerce because the world's natural products or advantages are not found in every part of the world, and therefore man can only gain for his use all natural products and advantages by exchanging commodities.

It is important to observe that this is true of each nation separately and of the world as a whole. Within the small confines of the United Kingdom, for example, there is the widest variation of natural products and advantages. The greatest British industrial asset is coal, but our coal is chiefly confined to the northern parts of England, to the south of Scotland, and to Wales. If, therefore, the British people lived in village communities without the exchange of commodities between those communities, dire poverty would be the lot of those dwelling on the greater part of British soil. Commerce distributes coal and the products produced by coal-power all over the country, and actually creates wealth where otherwise wealth would be almost entirely wanting.

But how much more the creative and fructifying virtue of commerce becomes apparent when we consider the relation of a man living in the United Kingdom to the wealth of the world outside these islands! The British Isles are wholly lacking in some of the metals, in many valuable woods, in a variety of fibres, in various miscellaneous materials such as rubber or ivory, and in many valuable cereals, vegetable products, and fruits. Without these things the British citizen would be condemned to the conditions of an exceedingly primitive civilisation, and, it may be added, without them the number of people living in these islands would be very small.

Commerce makes us citizens of the world, users of all the world, partakers in every harvest, workers in every field of industry. Not merely material things are thus called into existence by commerce, but lives are conjured into existence by its fruitful streams. Here commerce joins hands with biology. The point is so important that we must give it further consideration.

Why is it that man, alone among living things, *is ever multiplying his kind ?* When we examine the animal world we find that in ordinary course a pair succeeds a pair, and that, while there is a large number of births of each creature in each region, the number of birds or animals or insects or reptiles in each region remains almost constant. Let us consider the case of the fox. This animal has four or five at a birth, and it is fruitful for several years. If we imagine a pair of foxes to have merely six young, however, and no more, and that these are divided equally in point of sex, and that the three pairs of young ones each produce six young in the following season, the two foxes have, after the lapse of a year, become multiplied into twenty-six foxes. In ten years at this rate their number would be expressed in six figures. Why, then, does the world not run with foxes ? The explanation is that the Law of Nature is a Law of Death. The births are prodigious ; the survivals are few. Each region, the woodland, the field, the river, forms an almost self-contained group of lives, in which there is a balance of forces between various creatures preying upon each other. Food is limited ; however many are born, only as many can survive as find food.

How Man's Defiance of Nature has Changed the Conditions of the World

But man rises superior to the order of the nature from which he has emerged. As Professor Ray Lankester has said, Man is Nature's rebel. Where Nature says " Die ! " Man says " I will live." We refuse to submit ourselves to what would appear inexorable law. We till the earth and make a thousand blades of grass grow where one grew before. We produce and add a thousandfold to the value of our production by interchange with regions we have never seen. Where the fox or the tiger perishes for lack of sustenance, the young of mankind are sustained by supplies artificially created and gained largely by commerce.

The defiance of Nature which man exercises on his own behalf is exercised not only in regard to his own kind, but in regard to such plants and animals as he desires for his own purposes to multiply. And, it may be added, in that process of defiant multiplication man multiplies not only what he desires, but what he does not desire. It is difficult for the farmer to realise that he himself, by his kindly provision of a harvest, has actually created the sparrows which he detests, and it is even more difficult for man to realise that he himself breeds the organic diseases of his towns.

We see, then, how true it is that commerce is *not merely a creator of material wealth*, but a veritable creator of population. It is probable that the British Isles, if they had never engaged in commerce with other parts of the world, would at the present time contain less than ten million people, while the population of the world as a whole would be far short of its present 1600 millions.

Life for Millions where Nature Grudged Food for Thousands

Commerce, by bringing to our shores exotic materials, enables great industrial populations to live and multiply, and enables us to take full advantage of gifts which otherwise would lie dormant. The humidity, or excellent weaving weather, of the north-west of England is utilised by bringing raw cotton from across the Atlantic to be dealt with by hundreds of thousands in Lancashire who directly or indirectly produce the livelihood of millions of people. From every clime we draw commodities which engage the activities of our population and make use of our natural gift of coal. So it is that millions live where Nature grudged sustenance to thousands. So it is that millions in effect use the whole world in the islands where, not long since in the life of the world, a few painted savages, whose only acquaintance with foreign trade was an occasional visit from the Phœnicians, wrung a hard living from an unwilling earth.

Man gains wealth by commerce, in the second place, because the artificial productions of mankind are exceedingly various in nature and quality, varying with the widely differing gifts of the races of mankind.

The Key to the best use of the World which Makes Men and Nations Complete

Upon the superstructure of natural productions the races of man have reared thousands of arts, and the prime necessity of commerce, which is sufficiently apparent in relation to natural productions, becomes intensified by the remarkable individual and sometimes subtle qualities which the different races contrive to impart to their arts and manufactures. It is only partly true that " all can grow the flowers now, for all have got the seed." Not only as between different nations, but within the borders of the same country, we find the most extraordinary variation of adaptability to the arts, and not merely inequality of production, but indefinable though very real distinctions of form, or texture, or flavour, or fitness for a certain end, which make them desirable. A high form of civilisation can only be maintained by the power of access

to all the productions of all nations, and of all the groups within those nations, and commerce alone can give us that best use of the world which makes the complete nation and the complete man.

We do not know when it was that there emerged from the animal world a creature with a relatively capacious skull, a creature erect, skilful, and intelligent, which was destined to develop language, arts, and sciences, and to aspire to control the forces of Nature which had evolved him.

The First Trading Man and the Beginning of Exchange

We know that a hundred or even two hundred centuries ago he had begun to use implements. We do not know when he first notched a stick to make a calendar, or when he first exchanged the labour of his hands for the labour of others, but we do know that the first written records of man discover him, in the great river civilisations of the Tigris, the Euphrates, and the Nile, as a man of commerce. Fifty or sixty centuries ago commerce existed in Assyria, in Babylonia, and in Egypt—commerce limited in scope by the poor means of transport, but commerce, nevertheless, of no small order.

Our earliest picture of trading man is of a generally self-contained and self-sufficing tribe or clan of savages beginning as a group to exchange presents with another such group, exchanging skins for weapons, or implements for ornaments. Many centuries must have elapsed after man's first appearance on the earth before he was so far rid of animal fear and distrust, and so far possessed of intelligence and sociability, as to be able to make rude exchanges of goods for goods. The inconveniences of crude barter are obvious, but the early progress of mankind was slow, and again a long interval probably elapsed before tribes realised the importance of facilitating barter by measuring the values of all commodities by reference to some particular commodity.

The Long Step between a Beast and a Five-Pound Note

The beginning of money was the conception of a common standard of value, and the products of the primary industry of agriculture naturally furnished the first standards. As we find recorded in the Old Testament, the wealth of a man came to be reckoned by the number of his beasts. It is difficult to conceive a clumsier currency than cattle, but undoubtedly cattle in many lands came to be not merely a standard of value but actual money.

It is a long step from using cattle as money to paying for a commodity with a cheque or a £5 Bank of England note, and Carlyle was in too much of a hurry to bridge the gap when, in "Sartor Resartus," he made Herr Teufelsdröckh declaim: "A simple invention it was in the old world Grazier—sick of lugging his slow Ox about the country till he got it bartered for corn and oil—to take a piece of leather and thereon scratch or stamp the mere figure of an Ox (or *pecus*); put it in his pocket, and call it *pecunia*—money. Yet hereby did Barter grow Sale, and Leather Money is now Golden and Paper, and all miracles have been out-miracled, for there are Rothschilds and English National Debts; and whoso has sixpence is sovereign (to the length of sixpence) over all men, commands cooks to feed him, philosophers to teach him, Kings to mount guard over him—to the length of sixpence."

No; the beginning of token money was not so simple as that. It was long indeed before trust or credit enabled a man of reputation to write value on a bit of paper in terms of a standard currency, and to get that bit of paper accepted as being as good as cattle or gold. Nevertheless, the essential step was taken when Barter became Buying and Selling by the recognition of a Standard of Value, and by the use of that standard of value as an Instrument of Exchange.

Will the Day come when there will be no Money in the World?

When the early pastoralists, rich in flocks and herds, bought raiment in terms of cattle, man had advanced far indeed from that fierce, distrustful creature his original ancestor. The use of cattle as money appears in the early records of many nations, and even now remains on the earth. But while grain, animals, ornaments, slaves, have done duty as currency, the peculiar quality of the metals made it inevitable that iron and copper, and ultimately gold and silver, should supplant all other forms of money among advanced peoples. Finally, gold—because of its superior stability of value—has dethroned silver in nearly all countries, and established itself as the supreme standard of value and medium of exchange.

When we come to examine money in detail, we shall see that there is great hope that some day civilisation will be able to dispense altogether with a material currency, and to establish a theoretic money expressed in bits of paper, and based possibly upon units of work. In the meantime gold is the basis of credit; and while different forms of paper instruments are used as

mediums of exchange, they are all based upon the fact that they are exchangeable into gold. We have arrived, in fact, at a transition stage, in which we base ourselves on a gold standard, and, having done so, pass between us, as instruments of exchange, pieces of paper standing for enormous amounts of gold which *do not exist* in the world, pieces of paper which, if an effort were made to translate them into gold, would fail to be honoured. In practice we know that a cheque on a bank of reputation is an instrument creditable because represented in fact, not by gold, but by commodities.

A Demand for Gold which would Stop every Bank in the Kingdom

Confidence in the instrument, faith in the bit of paper, rests upon experience and general good faith, and it is assisted by the knowledge that it is only occasionally that actual gold is either wanted or demanded, and that at these times it is forthcoming.

Theoretically, the position which actually exists would appear impossible. Nothing but practical experience could have brought it into existence. We measure values by a gold standard, we make a very limited number of gold coins, and we then express a considerable part of the property in the country as gold values written on paper, and we honour these. We build up a strong yet delicate fabric of credit which, in ordinary times, serves us well. It rests upon confidence, however, and a simultaneous demand for gold by all those holding credit instruments payable in gold would bring the entire machinery to a standstill. If a not very large proportion of the people with bank accounts were to present cheques at their banks to-morrow for the amount of their deposits, every bank in the kingdom would stop payment. That would not mean that value in commodities did not exist in the country to meet every cheque ; it would simply mean that much property is expressed in gold, and is current as gold, which does not actually exist as gold.

The Foundation of the Machinery of the World's Trade

In theory, transactions between the trading individuals of different nations are also settled in gold. In practice gold is only remitted from one nation to another in payment for goods when it is found impossible to set off the exchanges of commodities between the nations concerned against each other through the machinery of bills of exchange which are in essence symbols of commodities. A bill of exchange is merely an order in writing from one person, whom we will call A, to another person, whom we will call B, requiring B to pay a certain sum, either on demand or at some future date, to A, or to some third party. A is said to " draw " the bill upon B. If B acknowledges the indebtedness, and agrees to make the payment on the date prescribed by the drawer, he signs his name across the bill, or, as it is termed, " accepts " the bill. The bill, thus accepted by a person of reputation, is a negotiable instrument, and can be used as money as freely and easily as though it were a piece of gold. It is a symbol of the transfer of goods from A to B, and is equivalent to an acknowledgment by B that he is prepared, on a certain day, to produce gold in settlement for the goods.

This simple bit of paper, this symbol of transfer, this instrument of exchange, is wonderfully effective and useful in practice, and it is the foundation of the machinery of foreign trade. Bills are drawn against the shipment of commodities ; and the bit of paper, by which the exporter of one country makes requisition to pay upon the importer in another country, becomes a piece of negotiable money—a token of, or symbol for, the goods to which it relates.

A Piece of Paper with the Value of Gold Wherever it goes

By passing these slips of paper between nations, the cross-shipment of gold, or gold payments, is almost entirely avoided. Debts are set off against debts, and the bartering of goods, which is always the essence of commerce, and is only disguised by reference to units of gold value, is simply and surely accomplished. The iron of Britain is changed for the wine or the silk of France, or, by a process only a little more elaborate, the iron of Britain may be shipped to Brazil and exchanged, in effect, not for a Brazilian commodity, but for cotton imported from the United States.

Distribution rests upon means of transport and locomotion, and commerce, therefore, has ever been circumscribed by the limitations of other sciences. Commerce is the debtor of the engineer and the scientist, but the stimulation of commerce has ever been a spur to the sciences connected with transport. In ancient days it was the economic stimulus which impelled Nebuchadnezzar to the construction of a mighty ship canal from Babylon to the mouth of the Euphrates on the Persian Gulf. In modern times it was the economic stimulus which called the steam-engine into being. The necessity of pumping water out of British coal-mines mothered first the

crude steam-engine of Newcomen, and led to the inventions and discoveries of Watt, Stephenson, and Brunel, who, by increasing transport facilities a thousand-fold, made modern commerce possible. The possibility of large scale and rapid transport has, in the last half-century, brought the ends of the world together, caused an unprecedented production and consumption of wealth, and quickly created a new order of economic problems of which the solution is still in doubt.

The Four Conditions upon which the Trade of Nations Rests

The main conditions of commerce now appear. They are four.

1. The combination of trust and confidence which we call Credit.

This factor was slow of growth. In the history of man the establishment of banking by the Italians is as yesterday, but the space from the beginning of man to the establishment of the Exchange on the Rialto is a matter of ages. To-day trust is so far the rule that perhaps there was never a time when a man without scruple could more easily find victims. We are so accustomed to credit that its failure here and there is but the exception which proves the rule of honour.

2. Peace and Security for the trader.

There is now no reasonable doubt that mankind has won through the worst of War. Such monstrous calamities as the utter destruction of ancient Tyre, such comparatively modern horrors as the laying waste of Germany by the Thirty Years War, have passed for ever. The wars of the nineteenth century, great as was their waste, were comparatively harmless to commerce, and in the twentieth century wars are likely to be fewer and briefer. Over the greater part of the earth peace and security prevail.

Tapping the Natural Resources of the World at a Prodigious Rate

3. Easy and cheap systems of Transport and Communication.

The marvellous work of the engineer has been a magnificent contribution to the means of commerce. The Roman built roads for all time, but the modern engineer has given roads a new meaning, and solved problems which might have saved the Roman Empire. The canalised river, the artificial waterway, the railway, and the steamship have, in the last eighty years, made it possible to use the world commercially as it was never used before. New wonders of the world have appeared in the Suez Canal, in the giant steamship, in the electric telegraph, in the wonderful feat of engineering now approaching completion at Panama. As a result, the natural resources of the world are being tapped at a prodigious rate, and it is already becoming apparent that a greater unity of the sciences is needed if man is to increase the interchange of the supplies upon which his civilisation depends.

4. An effective Machinery of Exchange.

We have seen how man has passed from crude barter to a marketing conducted by credit instruments. Existing processes have been so far perfected that almost every known commodity is easily procurable in the world's great centres of population. It is nevertheless true that the science of commerce, regarded properly as the Science of Distribution, is far less advanced than the Science of Production. In the twentieth century of our era we find it a much simpler matter to produce cloth, or furniture, or apparel than to secure by commerce a full supply of these things for all those who desire them. Here the problems of commerce join hands with those of Sociology.

A Function of Commerce which looks to Statesmen for Guidance

We may be well assured that in relation to all these essentials of commerce man is destined to make enormous progress. An increasing standard of life in all countries will breed an ever-growing confidence of man in his fellow men. International relations will improve through the better knowledge which casts out fear and suspicion, and through the increased interdependence of trading communities. The engineer and the scientist will continue the task of perfecting the links of communication and the powers of production, so that an ever-increasing volume of commodities will pour along the trade routes of the world.

Finally, the combined efforts of the merchant, the economist, and the statesman will enable the world to come to market in a sense transcending the commerce of to-day. Commerce, which already has high functions, will come to be universally recognised as a matter of the first importance, demanding the application of the highest faculties of the most gifted men. The ancient and ignorant contempt of the gentleman for the votaries of trade has already, in great measure, disappeared. The organisation of the production and distribution of wealth, perhaps in forms and by methods of which we have yet small conception, will come to be properly regarded as one of the chief functions of civilisation—a function which will look to every science for aid and to every statesman for guidance.

THE COMMON SPIRIT OF SOCIETY

The chief triumph of man is Society, upon which the maintenance of civilisation depends. In this picture a French painter has aptly represented the fellowship and mutual aid upon which Society rests.

HOW MAN GOES ON FOR EVER

The Wonderful Thing of Man's Making
which Lives on when its Maker dies

THE HUMAN REBELLION AGAINST NATURE

THERE has been a great deal of foolish talk about the future Superman. Nietzsche, a brilliant German writer, began it. Seeing that, according to modern science, the human race has gradually developed out of a low animal stock, Nietzsche assumed that mankind would at last disappear and make way for a still more superior type of being. It was supposed that the superman would be evolved by savagely intensifying the natural struggle for existence. Nietzsche has been aptly turned the *enfant terrible* of Darwinism. His was, however, a loose and blind way of thinking. He left completely out of sight the most momentous event in the history of the world. Man has not waited for the slow production, by any process of natural selection, of a super-humanity. He has created it. It is a strange, vast, and mighty thing, and it is called Society.

The fact is that man has now escaped from the ordinary pressure of natural conditions. He has grown to a tremendous height by transcending in a wonderful way the operation of certain laws of life. The last stage in the evolution of his physical powers is represented by those mechanical inventions which have enabled him to control external nature. The last stage in the development of his psychical powers is found in the moral and intellectual fabric of society by means of which he has been able to control human nature. In both instances man has overturned the ordinary process of growth and decay. He has fashioned something possessing the attribute of escaping destruction and continuing to work on the death of the living thing by which it is produced.

It is very probable that since man rose from savagery to civility, the general level of the intellectual capacity of the individual has not grown higher. The Dorian Greeks, the Romans, the Celts, and the Teutons acquired, in their primitive struggle with adverse natural conditions, the force of mind which they used in building up their civilisations. Yet, in spite of the fact that the mental powers of the individual have not increased for some thousands of years, humanity in that time has made remarkable progress in material comfort, in command over nature, in culture and morality. All these achievements are the direct results of an improved organisation of society, by means of which the paralysing limitation of physical heredity has been profoundly modified. This transcendence of an awful natural law is the first of man's greatest achievements over nature, and by far the most important. From it are derived all the other advantages now enjoyed by humanity, or brought within a prospect of enjoyment. Man's first grand revolt was his transcendence of a harsh, restricting law.

And how successful has been his rebellion! As his social progress is not wholly dependent on the forces that govern the lives of the brutes, he has been able quickly to create a glorious heritage of civilisation by means of which he supplements to an extraordinary degree the feeble powers which he obtains by natural heredity. A man now makes two bequests when he passes away. He still bequeaths to his children some of his physical and mental characteristics, but his high achievements—his mechanical inventions, and his moral, artistic, and intellectual conquests—he leaves to mankind. The Law of progress is that progress lies in the production and selection of useful variations, and certainly in the evolution of society there still obtains something like this Law. In social organisations, however, the fruitful variation is not the individual as such, but his surviving thoughts. Thus we may say that the growth of the social

fabric is similar to the growth of consciousness rather than to the growth of the physical body itself.

The modern civilised society is a sort of quasi-personality embodied in the common mind of its individual members. The forces of the social world, however, are as subject to law as the forces of the physical world. In it are currents of attraction and currents of diversion; some bring the individual under the sway of the group; others enable the single man to strike out into some independent and original line of action. Of course, the natural socialising power is the gregarious instinct of the human being. It may be a legacy from a remote animal ancestor. This instinct, however, is not very strong; even in the lowest races it

Man, in short, is partly a social product. His race is of small importance when compared with his social race-conditions; even the action of his physical environment is slight in comparison with that of his social environment. Plato held that man was born with ready-made ideas which could never be acquired by mere experience. Locke, on the other hand, contended that all the notions we possess have their origin in individual sensation. Philosophers are still disputing the matter; but, looking at it from another point of view, it is clear that Plato's wonderful world of ready-made ideas has some sort of existence. It is the world of society. It is not we who think, says Post, the greatest living authority on jurisprudence, but humanity that thinks in us.

IN THE VERY EARLY DAYS

has to be supplemented by a certain curious mental acquirement. Man differs from all animals in that his instincts are not rigidly defined, and the instinctive part of his nature becomes smaller as he grows up. The more a creature is destined to learn in its lifetime, the less rigidly defined it must be at birth in the matter of instincts and special powers. What we inherit is a capacity to learn, and not, like the animals, an ability to perform. It is the plasticity of our instincts which gives us so adaptable a nature; and this plasticity enables us to acquire by social heredity infinitely more than physical heredity could give us.

The child comes into the world like a piece of soft clay, and the community into which he is born does much to mould his mind and his character, his feelings and his habits.

But by what means does the individual acquire his social heritage? Here we come to the problem of that curious mental acquirement which supplements in the human being the instinctive ability of the animals. Man possesses in an extraordinary degree the faculty of learning by means of imitation. In this respect no monkey can compare with him. He is a marvellous mimic, and continually and unconsciously he mimics the modes of feeling, the frames of mind, and the ideas of the group in which he lives. This is how the intellect and character of a child are developed and furnished. A child turns to others as a flower turns to the sun, and he learns by imitation. Though few men and women know it, they also are constantly being moulded in a similar way. There is a certain mild form

of hypnotism which is called suggestion; and this force of suggestion is the real socialising power. It acts in the world of society in a manner dimly analogous to the way in which gravitation acts in the world of matter.

A modern crowd in a state of excitement often exhibits this force of social suggestibility in a more striking manner than a savage community. For, though more finely civilised, it remains sensitive to the action of the strange force which subjugates the individual in the interests of the group. Carried away by the wild spirit of an angry mob in, for instance, a political campaign, men sometimes lose their individual power of judgment, and do things of which they feel ashamed when they recover self-control. Mob action is an extravagant form of social suggestibility. By its hypnotic influence the spirit of the crowd enforces in an extreme way that social co-operation which is the ordinary requirement of any sort of common life.

SOCIETY AS THE PROTECTOR OF THE CHILD
From a panel representing Law in remote antiquity.

Social thinking is the healthy engine of progress both in the creative and the conservative processes of society, and behind it must be the emotional, constraining impulse of social suggestion. But when the emotion of sociality breaks all bounds historic cataclysms occur.

Certain conditions must, of course, obtain before a special emotion of sociality prevails in an extraordinary manner. If a Chinaman were swept up in an English mob which was wildly roused by some political question, he would not be moved by the spirit of the crowd; and a French missionary in Asia Minor would not feel the contagious frenzy which sweeps through a multitude of fanatic dervishes. Mob feeling acts only on men united by common habits of mind; it is an aberrant, violent form of the social force which has already made them resemble each other in qualities and culture.

In a purely democratic form of society, in which the social levelling agencies

have produced a general similarity of desire and an easily moved suggestibility, the spirit of the crowd is a most dangerous factor in the State; it is largely responsible for the destruction of real liberty and the prevalence of various sorts of licence. In this case a strong-handed tyrant, or a subjugator at the head of a foreign army, is necessary to restore discipline and order.

Happily, the defect of too docile a responsiveness to social suggestion does not always lead to mob action. Indeed, as a rule, it makes for a rigid conservatism.

The Chief Social Force in all Primitive Communities

On the one hand, it is responsible for freaks of fashion and epidemics of wild thought and blind feeling. On the other hand, it keeps alive foolish superstitions and outworn usages and conventions, and it produces inertness of intellect and stagnancy of emotion. Social suggestibility at its lowest is imitation reduced to mere repetition. A man does something just because it is "the thing" to do it—that is, because other people are doing it.

Unintelligent social imitation of this kind is the chief force in all primitive communities. It is probable that every individual savage is capable, in favourable circumstances, of some degree of invention, but the social group to which he belongs compels him to live entirely by imitative routine. All social actions thus become by repetition rigid social habits, and the principle of growth and progress is entirely lacking. Human society in the purely imitative stage of culture is scarcely a higher form of organisation than the animal societies which are maintained by mere gregarious instinct. One of the few good results of war is that conquest does sometimes break down the purely imitative organisations of some of the lowest races. When the victors owe their victory to some sort of social progress, they introduce among the vanquished new elements which perhaps stimulate their latent powers of invention.

The Imitators who carry on the Experiences and Achievements of the Race

On the whole, however, the social imitative spirit of mankind is an instrument of sane and steadying power. Some important societies have been preserved by the mere repetition of thought and custom, especially when there was much sound matter in the traditions established by the ancestors of the race. Sparta, so unprogressive when compared with Athens, is an example of this healthy conservatism; and China, which has outlasted all the progressive empires of the ancient Western world, is a still more remarkable example.

In a general view, the social spirit of imitation is more effectual and more important than the individual spirit of originality. It preserves and carries on all those grand traditions, those vital conventions and instruments of civilisation, in which are resumed the experiences and achievements of the whole human race. Burke has said that no man could trade on his private stock of reason. As a matter of fact, reason is a social thing; it is by imitation that a child acquires the supreme faculty of speech, and the thoughts he develops by means of language. A solitary man could not live a full life even on the results of the best sort of conscious education.

In many social matters one learns in a glimpse, by imitative suggestion, more than could be acquired in many hours by explanation and study. The life of the individual is short and shallow, but the traditional wisdom of society is far-reaching and profound. And, seeing that our intellectual and emotional habits are mainly formed by social suggestion long before we come to think partly for ourselves, it is impossible for the most independent mind to free itself sufficiently to criticise its own foundations.

Will a High Civilisation Utterly Abolish the Human Struggle for Life?

We are all social products rather than social units. No doubt during our generation society is largely embodied in us, yet we do not represent the whole of society.

> Imperial spirits
> Rule the present from the past,

as Shelley said; and in the social conscience the interests of the future are also guarded.

Some thinkers have endeavoured to show that enlightened self-interest would make a man a good member of society. This, however, is a mischievous view. For it is possible to make rules of individual action which contain the highest wisdom and are yet unsocial. These rules would be those dictated by discretion and convenience, expediency, and the attainment of personal happiness. Such motives are indeed found in all defensive and aggressive organisations, and in most of the productive and distributive agencies of civilisation. Intelligent, self-regarding action, with the aim of success, is now widely employed in political and industrial life, and on its apparent utility in these fields there has recently been formed a gospel of national efficiency.

Little or no progress of society, however, can be effected by organising all the machinery of a nation on purely scientific lines. For society is at root an organisation for the development of social morality. By means of it, the harsher struggle for life has been mitigated with a view to its entire abolition. The only natural struggle which is valid in the highest sort of human civilisation is the struggle against the agents of disease. Here, until less than a hundred years ago, man unconsciously competed against man in a fierce selective process in which the microbe acted as the selector. It wiped out weak stocks and individuals with feeble constitutions, and by a long, agonising struggle it forced the race to keep strong and immune. Alcohol and narcotic drugs are also selective agents in a natural struggle between the members of society. Now, however, the community is beginning to protect all its members even against these natural agents of selection. This is the supreme triumph of social morality.

As society does so much for the individual—gives him his language, his feelings, his thoughts, his craftsmanship and industry, his customs and institutions, his creed and his government—surely society has the right to restrain his purely selfish interests when these conflict with the interests of his companions and the interests of future generations. This restriction is effected by means of the social conscience.

Now we come to a very interesting but somewhat difficult point in our examination of the relations between the individual and the community. We have seen that to a large extent the mind and character of a man is a social product; and so, too, is his sense of right and wrong. To put it briefly, a man cannot think of himself except in terms of other men. As a psychologist would say, the social situation is implicated in the thought of oneself. A man does not need to consider "What will people say of this selfish action of mine?" His conscience tells him; his conscience represents the social force in its highest and purest incarnation.

DESPOTISM AND CIVILISATION ONLY 20 YEARS APART

These two pictures show in a striking way the rapid spreading of ideas in society. The upper picture shows a law court in old Japan; the lower picture shows the Japanese Parliament fully established less than 20 years later.

This seems intelligible at first glance, but in one of the last of his writings Huxley raised an apparently well-founded objection. His point was that if the moral sense were the outcome of social relationship, then a man ought to feel an obligation to perform the bad acts in which society indulges, as well as the good acts. Now, this really happens in certain circumstances. Very young children, for instance, sometimes feel impelled to imitate everything; a selfish action arouses their selfishness, and a generous action provokes their generosity. A somewhat similar thing is seen in savages of an inferior type, and it perpetuates the horrible vices and the sanguinary customs of very low races. The individual begins by imitating both the good and the bad elements in the social group. In civilised societies, however, this natural lawlessness is corrected by conventions and laws and religions, in which the best spirit of the race is embodied.

"PANELS OF THE PEOPLE," SUGGESTING THE ADVANCE OF SOCIETY TO A HIGH STATE OF

But, in order to create any kind of improvement whatever in social organisation, a man must rise superior to the society in which he lives. In other words, the socialising power of imitative suggestion must be supplemented by the individual faculty of invention. There are, however, so many constraining and levelling social forces that it seems as though the individuality of a man is thereby suppressed.

This, however, is not the case. The better organised a society is, the greater is the power of the individual. To put it in a paradoxical way, the more imitative a person is, the more original he will become. To a large extent both genius and talent are based on a capacity for real assimilation. The more living knowledge a man obtains, the greater powers of thought and creative imagination he develops. Genius is measured by its scope. Minds of the highest order, such as Shakespeare's and Newton's, have an extraordinary faculty of assimilation. In such minds are brought together for the first time elements of knowledge which formerly existed only in scattered traditions or separated sources of information. Their originality consists in making a novel combination out of pieces of old material.

This may seem a poor kind of originality, but it really is creativeness of a supreme kind. It is the sort of creativeness on which the progress of society entirely depends. This is explained by the profound difference between the world of matter and the world of mind. The world of matter is composed of a mass of energies varying in appearance but unchangeable in quantity; nothing can be added to it; there is no progress in it; only a process of evolution and dissolution. But in the world of mind there can be a continual creation of new elements. There is no justification for saying that a physical fact is new merely because it has just been discovered; but every new idea brings into the world of mind something which did not exist before. If it is a great social idea it may give a new direction to the course of human development and increase the powers of every individual.

For the powers of each individual are augmented by every improvement in socialisation The richness of his social heritage is extended; the amount of contemporary knowledge at his disposal is made greater; and his personal influence is widened and deepened. His inventions may revolutionise the life of the community; his discoveries may add vastly to its resources; his literary work or scientific writings may set the aspirations of a nation and mark an era in the history of mankind. When we remember that the modern steam-engine was once only an idea in the mind of a Glasgow instrument maker, and when we recall that Watt found the engine a practical

CIVILISATION IN WHICH THE BITTER STRUGGLE FOR LIFE WILL PROBABLY ENTIRELY DISAPPEAR

machine, and only slightly improved on a first principle of mechanics already worked out in practice by innumerable men, we can see clearly how small the originality of an individual may be in quantity, and yet how vast it may be in quality. In the world of thought it is often the little new things that tell, especially when the slight novelties are closely related to older achievements, so that the development appears natural and involves little divergence.

Too great an originality of mind in the individual is sometimes fruitless. It is rightly said of men of the stamp of Roger Bacon that they were born before their time. The new thoughts of an inventive mind must be only a little above the average intelligence if they are to produce an immediate and a wide effect. In other words, they must be capable of being socialised by general imitation. It was by imitation that the inventor acquired his materials from society, and it is by imitation that society, in turn, acquires from him his new idea. The need for campaigns of education to effect the most evident of social reform shows that the general mind of the community is usually on the side of the average conservative man. So the less distance there is between a new idea and the traditions from which it is worked out, the less resistance there will be to this idea becoming incorporated in the social fabric. When we talk of inventive minds, especially in connection with the progress of modern civilisation, we do not refer exclusively to men of genius or superior talent. Every normal member of a highly civilised community possesses some initiating power. Few civilised men live a life of purely repetitive imitation; by their work, by their example, by a thousand little unremembered acts, they play some part in casting the social heritage into a better or worse form, and in handing down this new form to the next generation. One of the chief results of the new science of society is to rehabilitate the power of the individual. Instead of regarding social institutions, ideas, and sentiments as the spontaneous product of the nameless multitude, modern science rightly considers them the achievements of individuals. The individual genius, however, is mainly a product of the social spirit, and its new ideas, in order to be effectual, must be consolidated, diffused, and preserved by imitation in the social mind. Then, from the contents of the social mind, the materials for new inventions are in turn obtained by the great minds of the next generation. Thus there is a constant give and take between a society and the individuals composing it, and out of this give and take, in favourable conditions, the forces of progress are evolved.

What is it that contributes most to the development of a community? Some men

of science, we are afraid, might be tempted to reply that intellectual power, and the wonderful knowledge now being obtained by the exercise of that power, are the grand factors in social progress. But the truth is probably that a higher morality, a finer and more sensitive conscience, are the main things necessary to the development of human society. In order to get men to co-operate in promoting the general welfare, we must first break down the barriers of selfishness. Selfishness has many shapes, some gross, some subtle, and it is probable that many men, in following their own personal ends, have indirectly done social good. But, as was said before, the most enlightened self-interest is not a true form of sociality. No self-interest, however enlightened, will by itself lead a man to act for the benefit of future generations. Yet, whatever any man holds, he holds purely as a trustee. It is a legacy slowly accumulated by tears and blood, by struggle and self-sacrifice, of innumerable generations of men and women who have gone before us. It is our duty—and it ought to be our pleasure—to sacrifice a little of our comfort and devote a little of our labour to the task of improving this legacy of society, and thus doing for those still unborn what those now dead did for us.

THE PUBLIC BURNING OF OPIUM PIPES IN CHINA

New forces are quickening the heart and mind of all the peoples of the earth, lifting them up on the wave of common hope into a higher state of civilisation; and no national example of this uplifting movement can compare, in dramatic intensity and far-reaching potentiality, with the national war against opium in China.

The question of social progress is now largely a question of the development of social morality. Having mitigated the primitive struggle for existence and come to co-operate together, we must moralise natural law, by a deep-seated feeling of love for our fellow-man. As struggle is the older law of Nature, so love is the spirit of society, and thus the new law of Nature. It is by no chance that Christendom, despite its disinclination to put in practice the Sermon on the Mount, has become the centre of a civilisation which is radiating over the earth, even in Japan and China, in Persia and in Turkey, and producing vast revolutions in these ancient states. For modern Christendom is the best example in history of socialisation on a large scale. It combines a useful diversity of languages and local traditions with the unifying factors of common creeds, similar institutions of learning and government, and a vast common fund of culture. As the recent congress of races shows, there is now beginning to obtain a larger sense of commonalty, and new forces are quickening the heart and mind of all the peoples of the earth and lifting them up on a wave of common hope into a state of civilisation far higher than any that has yet existed.

No doubt the steamship and the railway and the telegraph have brought nations into closer contact, but mere contact is not society. For thousands of years neighbouring nations have traded together without finding in commerce a consolidating and pacific power. What was wanting was an overspreading atmosphere of high thoughts and large feelings derived from some universal socialising power. This power has at last been created by the New Reformation begun in Christendom. By happy fate the movement of social reform occurs in an age of mechanical invention and scientific progress; and, instead of failing in the various ways in which similar movements have failed, it has increased in steadiness and scope and orderly growth, and inspired men with new ideas of human society.

It is the influence of these ideas which is transforming the mere physical contact of the nations into a sympathy of aspirations and a communion of thought. Thus all men are at last gathering into one society, bringing with them fresh sources for the production of those new and fruitful variations which make for progress.

THE TRANSFORMER OF SOCIETY

It is by no mere chance that Christendom has become the centre of a civilisation radiating over the earth, for Christendom is the historic example of socialisation on a large scale, combining diversity of language and tradition with common creeds and institutions. We may think of Paul, therefore, as a great transformer of society, who, in saving Christianity from becoming narrow—by talking to his gaolers or by writing letters from his prison-house—gave new strength to a spirit which has woven itself in the very structure of the modern world.

THE GATES OF • DAWN

Reproduced by permission of Messrs. C. W. Faulkner

BY HERBERT DRAPER

THE PEOPLE CALLED EUGENISTS

The New Science That Would Control the Future and Create a Nobler Race

WILL LOVE TURN IT UPSIDE DOWN?

THE people called Eugenists believe that the soul of all improvement is the improvement of the soul; that, since individuals are mortal, the quality and quantity of parenthood are the dominant factors in the destiny of any people; that the culture of the racial life is the vital industry of mankind, everywhere and always; that every child who comes into the world should be planned, desired, and loved in anticipation; that the function of government is the production and recognition of human worth, and the extirpation of human unworth; and that to these incomparable ends, for which the world was made, all powers of man and of Nature, all forces, spiritual and material, must be made subservient.

These people number among them all the great thinkers and students of mankind, all who have perceived and striven, and whose spiritual heirs we are. Plato was a Eugenist, no less than Galton. The great poets are Eugenists, one and all, as a noble volume might be occupied in proving. They have all known in their hearts what Whitman knew, when he said: "Produce great persons, the rest follows," and what Wordsworth knew, when he asked:

> What one is, why may not millions be?
> What laws are set by Nature in the way of such a hope?

Let us be assured that this is no new fad, but rather the modern form of the idea and the ideal to which the noblest men and women of all the past have consecrated all their powers.

Its modern characteristic is, as we find in every other sphere of thought and action, that it has become informed with science. The people called Eugenists desire and hope for what all people worthy to be called human have desired and hoped for—the coming of nobler and finer men and women, the disappearance of disease and ugliness and misery and vice, the making of a better world, the dawn of the Golden Age which poets fabled in the past, but towards which we know our feet are pressing.

But Eugenists say that if these ideals are to be achieved, more is needed than noble statement of them, more than prayers and tears and faith, more even than hope and courage. "To work is to pray," and the call to-day is for the faith which works. The task is our task, because we are also, in the great phrase, "partakers of the Divine nature," and are called upon to do our part in the task of creation. We generate the race, and we must regenerate it. The records of the past give us our warrant of possibility, if we consider whence we have sprung; they give us all-important guidance as to principles and methods; and while the past thus teaches us, it also inspires us with the idea of a mighty debt which we owe to the past, and can only pay to the future. "To the solid ground of Nature trusts the mind which builds for aye." If we are to build a nobler race, which is greater than building noble cities, and is indeed the object of building noble cities, we must lay our foundations in this solid ground.

At this point Eugenics, which was already seen to be a religion, is seen to be a science also. If we are to practise our religion, we must bring science to our aid, and we shall later discover, more clearly every year we live, that not one science nor two, but many, if not all, are called upon to contribute their share of guidance, warning, and inspiration for the people called Eugenists.

The time has come when these people are definitely called upon to state, not so much their creed, as their proposals for

translating that creed into deed. The eugenic idea is accepted; the first articles of the creed have won assent, hearty or formal, active or passive, from all people. They are beyond challenge. If our campaign is to remain there, everyone may say that "We are all Eugenists nowadays," just as Sir William Harcourt said: "We are all Socialists nowadays." But Socialists reply that, while this is in a sense true, they nevertheless are a distinct people, not because they have a distinct object—for we all want everybody to be happy—but because they have a distinct theory as to how that object may be attained. Just so, Eugenists reply that, though all men desire what they desire, they are nevertheless a distinct people, not only because they keep that end more clearly and whole-heartedly before them than other people, which is certainly the case, but because they have a distinct theory as to how this desire of all men may be attained, a theory which is not the aristocrat's or the Socialist's, but is original with the Eugenist, and with him alone.

What are the Factors that Make all Types of Men and Women?

Here, then, the writer sets forth the practical and immediate principles which must be admitted by Eugenists, according to the development of his thought during the past eight years. As it appears to him, the people called Eugenists are therefore called upon to admit these principles if they are to be true to their creed; and though some of these principles may be more important than others, or more practicable or more urgent, none must be omitted, for all are essential.

It being granted that our object is the making of noble individuals, we have first of all to ask ourselves: What are the factors that make the individual noble or base, healthy or diseased, tall or short, clever or stupid, kind or cruel? The answer is clear. Every attribute and character of every living being is the product of what we may conveniently call "Nature" and "Nurture." These terms were adopted by Sir Francis Galton from a phrase of Shakespeare's, and they are so convenient and apt that they are rapidly coming into general use. The student knows that they are invaluable and indispensable at every stage of his study and interpretation; and they must be considered in detail later. Meanwhile, we recognise that "Nature," including heredity as that is usually understood, and also everything else given at the individual's beginning, though it may be unlike anything possessed by the parents; and "Nurture," including all nutrition from the moment of the formation of the new individual onwards, all environment, physical, social, spiritual—that these two cover between them, if they be properly understood, the whole of the forces that make us, or that make any living being, past, present, or to come. And we recognise that both are essential, for if there be no nature, nurture is impotent; and if there be no nurture, nature comes to nothing.

The Great End of Eugenics is Fine Germ-cells for Fine People

If this be granted, we have made a great stride. The people called Eugenists, while proclaiming a new doctrine, must assert their assent to an old doctrine, and must admit it to be *no less essential* than their new contribution to the argument. They must admit the whole of Nurture. It is not as if the end of Eugenics were the production and mating of fine germ-cells. We want not germ-cells, but people; and we want germ-cells, however fine, only because they develop into people. We must therefore nourish them, at every stage from the first to the last. This establishes, for instance, the case for the care of expectant motherhood as essential to Eugenics, though many professing Eugenists protest at this point, and call the care of a child before it is born "Socialism," and the "end of all things," including religion—though to pay later, in children's hospitals, for our neglect of the unborn appears to them charity, and therefore religious. This kind of folly has only to be exposed to be despised, and we need say no more of it in this place.

Are all Men Born Free and Equal into the World?

There is therefore a Nurtural Eugenics, an essential and integral part of our science and our practice. The asserted opposition between eugenics and social reform, eugenics and education, eugenics and philanthrophy, does not exist. The Eugenist accepts, welcomes, seeks to extend all the agencies that make for better nurture, alike for rich and poor, born and unborn. If and when he quarrels with those who are nowadays sometimes called the environmentalists, and thereby denies the value of environment for his own ideal, he is talking nonsense, and arousing opposition between those who should be friends and allies.

But the difference between the people called Eugenists and all other people

whatsoever lies in the fact that they recognise the factor of "nature," or heredity, *as well as*, not in place of, the factor of "nurture," or environment, in the making of human beings. If partisans, calling themselves Eugenists, desire us to exchange the obvious half-truth called "nurture" for the obvious half-truth called "nature," we must not listen to them. But the Eugenist is compelled to insist that his *special* contribution to the whole truth is necessary and essential, and that the whole truth cannot be seen without it.

The Eugenist maintains that when we say "All men are born free and equal" we are stating a truth or an ideal which is political, not biological. The political truth is glorious and never to be decried; but neither must it be confounded with the biological truth, which is that, vitally speaking, not only are all men not born free and equal, but all men and women are different, and some are as certainly doomed by their nature to inferiority and slavery - not political slavery —as others to superiority and freedom. If all children begin alike, and if the differences between men are therefore all due to nurture, then plainly what we here define as Nurtural Eugenics is the whole of eugenics. But if children differ inherently, and if these differences are not accidental, but proceed by law, and if they range from the criminal lunatic to the saintly genius, from the blight of disease to the radiance and wholeness of health, then plainly Nurtural Eugenics is only a stage of the whole making of a man or a woman, and not the first stage, but the second.

SIR FRANCIS GALTON, THE ILLUSTRIOUS FOUNDER OF MODERN EUGENICS

Now, this argument exactly consorts with the experience of the last seventy or eighty years, in which, to consider our own country, so much has been done for social reform, including the nationalisation of education for the latter half of the period. On the whole, the record is one not of the ennoblement of life, or, if it be so, at any rate too much remains to be done. We have wrought enormous improvement in the conditions of life, in housing and drainage, in diet and water supply, and in what is called "education," but should never be so called without quotation marks, to indicate that there is another and better use of the term.

All these and much more have we attended to, but the weightier matters, or the primary matters, of the law of life have been forgotten. We have cared for the feeble-minded girl when she got into trouble, and for her feeble-minded child, when she got into trouble; and we now have all three generations sometimes living together in the same workhouse. No doubt it is a fine workhouse, well ventilated, with large grounds, which provide for its expansion. And we have taken good care to ensure that its expansion will shortly be required; for we have actually devoted ourselves to "nurture" in such a fashion as to ensure, guarantee, and multiply the quantity of defective "nature" in each succeeding generation.

This, then, to take only one instance—an urgent and soon to be corrected instance, fortunately—is what the Eugenist means when he declares that the factor of "nature" or heredity has been forgotten; and even that it would be and is quite possible to attend to nurture in such a way as rapidly to cause the degeneration and complete ruin of a race. For instance, we might and do take great care of defective children, and of the defective babies of defective mothers—as we certainly should, but we also neglect myriads of healthy babies and healthy mothers. It can be demonstrated that in many instances these huge national experiments—far worse than any that the anti-vivisector objects to —ensure the survival of a much larger proportion of feeble-minded than of normal children. Plainly, our care must become more careful, our philanthropy more philanthropic; or in a few generations the end would be in sight.

Only too frequently, the people called Eugenists attempt to buttress and present their case with illustrations which do not illustrate but merely darken counsel. For instance, they argue that the race is

degenerating because the birth-rate is falling more rapidly among the middle-class than among the artisan class. It may be so, but it requires proof; and there is not the shadow of a scintilla of proof forthcoming—no, not though we wade through a wilderness of statistics, which one and all omit to consider the differences in nurture between these two classes. This kind of argument is worse than worthless for the eugenic case; but the wise Eugenist will instance the feeble-minded, and will convince therewith and forthwith all but the very feeble in mind.

Now, if "nature" be so important, if the degree of its importance becomes more evident and massive and minutely detailed with every year of investigation, and if the experience of all who breed cattle or roses or horses or peas proclaims the same truth, are we not bound, by the highest of moral sanctions, to apply our knowledge to the incomparable and superlative case of breeding men? To this question the people called Eugenists return the answer that this is our duty; that, notwithstanding all difficulties of ignorance, prejudice, convention, legislation, or public opinion, that duty must be done, and that the time to begin doing it is now. Slowly, but as surely as the very flux of Time, man will conquer these difficulties; the fools and the cynics and the impotent, their laughter and sneers and yawns, will pass into the jaws of darkness already gaping for them, and it shall be seen that the forces which have erected man from the brute and the worm are not yet exhausted in him, for they have their perennial source in the inexhaustible. The river of life is still flowing to the sea; this is but the delta yet, not the Great Deep.

If we are to conquer we must obey. Both hands, both eyes, both halves of our brains, both halves of every truth, are needed for our purpose. We must make a fresh start, and to our Nurtural Eugenics, which everyone is agreed upon, we must add a Natural Eugenics, which everyone shall yet be agreed upon. If present people will not, or cannot, see it, it will breed those who will and can!

Now, these two portions of Eugenics, corresponding to the two stages in the history of any individual, the stage of providing the material, and the stage of developing it, must be put in due relation to one another; and plainly we must speak of Natural or Primary Eugenics, and Nurtural or Secondary Eugenics. These

"ALL THINGS HUMAN BESTIR THEMSELVES AND VANISH"
From Plato, one of the first Eugenists.

THE STREAM OF LIFE THAT GOES FOR EVER FORWARD
From the painting by Mr. C. W. Wyllie

terms do not grade the importance of "nature" and "nurture"; that is a kind of folly practised by those who measure life on paper, with no idea of a living thing. If both are essential, there is no more to say.

But Natural Eugenics is to be called primary and Nurtural Eugenics secondary, because that is their order in time, that is their order in logic, and that, notwithstanding all our doings hitherto, must be their order in practice. For the first time in the history of modern civilisation—Sparta and Israel were forerunners—we are about to begin at the beginning, which, for each of us, is our "nature," our parentage, through the germ-cells whereof we were compounded. This is not sufficient, but this is primary, and nurture, even including ante-natal nurture, is secondary; this must we do, and not leave the other undone.

No more need be said at this point regarding Nurtural or Secondary Eugenics. We shall see in due course that, though this is not the special contribution of the people called Eugenists, they have their own view of it, and a very illuminating view it is. We shall see that, while others agree about the nurture of the adult, say as to housing, or the nurture of the adolescent and the school child, and while lately public opinion has discovered the infant, the Eugenist alone has discovered the wonderful, familiar, hitherto forgotten truth that *every one of us is alive for nine months before we are born.* When people insist on nurture, as they always do in the company of the Eugenist, he replies: "Very well; to nurture you appeal, and to nurture you shall go. It means more than you bargain for. Every expectant mother in the land involves the nurture of the next generation. Is there one expectant mother in England who is ill nourished, unprized, dishonoured, worried, overworked in factory or home? If so, be as good as your word; and if you believe in nurture for the next generation, begin its nurture now." This is one of the great issues of immediate progress, and none of us will live to hear the end of it, though the National Insurance Bill provides an iota of the beginning. Here one only makes a preliminary note—that nurture, like most other words that mean anything, means more than meets the casual eye or ear.

But now as to Natural or Primary Eugenics, as we have proposed to call it. This is the really new and peculiar contribution of the peculiar people called Eugenists, and it demands our specially careful and emphatic statement here. The term "Eugenics," or good breeding, was introduced by Sir Francis Galton in reference to the possibility of breeding, more largely than heretofore, from "able" stocks, whose members would presumably be of special value to the community. That would be a eugenic selection practised among mankind. But all selection must really involve rejection; to choose is also to refuse; and eugenics must include not only selection of the "able," or the worthy, but also rejection of the unworthy, like the feeble-minded,

as those who are to become the parents of the next generation. The writer, therefore, proposed that the original or Galtonian eugenics should be called positive eugenics, and that the converse should be called negative eugenics. These terms were approved and adopted by Galton, and have found general employment. Positive eugenics we shall define as the *encouragement of worthy parenthood*, and negative eugenics —that is to say, good breeding in a negative sense—we shall define as the *discouragement of unworthy parenthood*. These are perfectly clear principles. Their practice may and does involve difficulties; it may even be largely impracticable, but these are indisputable and cardinal lines of action.

To these two objects of Natural or Primary Eugenics a third must be added. Unfortunately, Eugenists have not yet realised its importance, and, indeed, it involves a number of new questions and difficulties. The proposition here laid down is that, if there be any agencies or substances at work which are capable of converting worthy stocks and worthy parenthood into unworthy stocks and unworthy parenthood, it is the duty of the Eugenist to combat those agents. Students of heredity are satisfied that if a man loses a limb, for instance, or suffers blindness or facial disfigurement from smallpox, his subsequent parenthood is not prejudiced. His children will not lack limbs, nor sight, nor healthy skin. These are instances, which might be multiplied to any extent, of parental damage or poisoning which does not affect offspring, and therefore scarcely concerns the Eugenist. But the few who have paid special attention to this highly obscure department of heredity are aware that certain agents are as definitely capable of injuring parenthood, by their action on the parental tissues, as others are not, and to these substances the writer has given the now generally recognised name of racial poisons. They injure the individual, though some may yet be found that do not injure the individual; but their supreme importance lies in the fact that they poison the race, by direct action on the germ-cells, of which the individual is the trustee and the host, and therefore we shall call them racial poisons, and sharply distinguish them from substances which injure the individual alone, however gravely.

The existence of agents belonging to this category is questioned by no one, though there is great need for further knowledge as to many agents which should probably be added to the list. What the agents are is not our concern here, though it may be briefly noted that the most important of them in this country are the obscure toxins produced by the parasites of certain diseases, and three well-defined and familiar substances—alcohol, lead, and arsenic.

A GREAT PRACTICAL EUGENIST—PROFESSOR METCHNIKOFF IN HIS FAMOUS LABORATORY IN PARIS

THE GREED THAT IS TOO OFTEN BEHIND INDUSTRY, WHICH EUGENICS WOULD ENNOBLE

From the painting by the late Mr. G. F. Watts, R.A., photographed by Frederick Hollyer

We are now in a position to complete our statement of Natural or Primary Eugenics. We require not only to encourage worthy parenthood and to discourage unworthy parenthood, but also to combat the racial poisons, which are liable to turn worthy into unworthy parenthood. The writer has adopted the term Preventive Eugenics to indicate the prevention of the racial disease caused by these racial poisons.

With this the principles and the categories of the Eugenist are completely stated, so far as present knowledge goes. One is compelled to recognise that more may yet be possible. It may be shown that certain agents, brought to bear upon the individual, directly improve his parenthood by changing for the better the germ cells which he bears. At the present time science knows nothing of any such definite agent, and therefore what might be called a constructive eugenics must be left for the future if possible, to practise. Meanwhile, the foregoing terms and definitions exhaust and comprehend the possibilities. In tabular form we may set them down in this way:

NATURAL OR PRIMARY EUGENICS

1. POSITIVE—encouraging worthy parenthood.
2. NEGATIVE—discouraging unworthy parenthood.
3. PREVENTIVE—opposing the racial poisons.

NURTURAL OR SECONDARY EUGENICS

1. PHYSICAL—including nurture from the beginning—not merely from the cradle—to the grave.
2. PSYCHICAL—including education.
3. SOCIAL AND MORAL—home, school, and nation.

No one knows better than the Eugenist who has spent years in the formulation and study of this programme how many questions it raises, and how many difficulties it involves. All manner of preliminary issues have to be dealt with, even before we attempt to put these principles into practice. We have to agree as to what we mean by worth and unworth; or, if not to agree, to obtain sufficient general consent; and the issue of the racial poisons—for the bare recognition of which the writer has struggled for years, with only now incipient success—involves problems which will not be solved in a generation. When we have decided what we are to call worth and what unworth, we have to ascertain to what extent, in what ways, how through the fathers, and how through the mothers—who are half the race, but are forgotten by many Eugenists—these qualities are inherited—a task which involves the study and disentanglement of human qualities, such as "vitality" or "conscientiousness," to a degree of which few, even among professed students of physiology or psychology, have dreamed.

The Eternal Question—Will Love Turn Eugenics Inside Out?

Even then our real difficulties have scarcely begun. Granted that our principles are agreed upon, that we know what we want and what we do not want, and that we know just what particular individuals, and what particular matings of individuals, will produce what kind of children, now we have to ascertain the methods by which the right people can be persuaded to become parents and the wrong people dissuaded or excluded, and the methods by which we can induce the right people to marry the right people, *for them*, if any such methods there be.

Meanwhile we shall encounter human instinct and passion and pride and prejudice and politics and custom at every turn; and, above all, we shall encounter the great fact of love, which makes the world go round, and may be quite equal to turning eugenics upside down and inside out. We shall have to decide whether this natural fact of love is an enemy of eugenics or a friend; and if it be designed to be a friend, as we shall discover, we must search out and destroy all those agents, such as Mammon and Bacchus, which are apt to pervert it and make it useless for the eugenic cause. Not least of all, we shall have to ascertain whether eugenics can be achieved without injuring the individuals through whom we work, or whether what is best for the individual is worst for the race, and the devil does indeed sit on the throne of the universe. This, also, we shall find some to assert.

But notwithstanding all these difficulties, notwithstanding all the difficulties there are or will be, the people called Eugenists are consecrated to this task.

The Modern Joshuas Marching Round the Walls of Jericho

It may not be possible to ennoble all mankind at once, or to banish all vice and disease; but the Eugenist may encourage his daughter's love of a fine young man, rather than push the claims of a rival who is better-to-do, but has a tendency to drink. He may not be able to overthrow the walls of Jericho and reconstruct society on a eugenic basis simply by sounding his trumpet, but he may write to his member of Parliament and ask what he is doing about the Reports of the Royal Commission on the Feeble-minded, and the Departmental Committee on the law regarding inebriates, and whether he is prepared to draw attention to the shameful and inexcusable delay in acting upon those reports, which have the honour and misfortune not to come into party politics, though involving the principles by which all parties will in the last resort be judged.

Everyone can be a centre and irradiator of eugenic opinion, everyone can do something to justify a claim to inclusion in the eugenic party—the party which knows no party and is no "respecter of persons" because it is for all, and because it is pre-eminently the respecter of persons, honouring and seeking to produce fine persons and fine personalities everywhere, by every means, caring nought for any other consideration.

The Foundations of Generations Nobler and Nobler Yet

Those who subscribe to the foregoing creed, who work for this end and no other, whether on a small scale or a great, humble in success, courageous in failure, absolutely and ineffably confident always that the future will witness more than they can dream of, content to lay the foundations of many generations, nobler and nobler yet, and to pass away ere the fruits of their handiwork can ripen or even the seed be sown, those who are dedicated to these ends, those whose personal ideal is this spirit and this temper, and whose racial ideal transcends even their dearest dreams—those, faint but pursuing, are the people called Eugenists.

POWER BEYOND OUR DREAMS

The Marvel of Creation that Grows more and more the Deeper we see into it

THE FOUNDATION-STONES OF THE UNIVERSE

Our first survey of the universe was outwards. We transcended the limits of our planet, contradicted the impression of centrality and immobility which it imposes on our minds, and realised the idea of the universe as a company of worlds, suns, and planets, of which we cannot even say that we are a great part—so far as measurement in terms of time and space and number is concerned. We did not discuss, at that first survey, questions of starry distances, the width of the Milky Way, nor "the time it would take an aeroplane to travel to Sirius." These questions of the outward magnitude of the universe will come when we try to face the problems of time and space; and meanwhile we have gained one great idea from our outward gaze. The universe is a company of worlds.

Let no one, however, though he be the most expert phrase-maker in the history of letters, suppose that he can encompass the universe in any formula. It is a company of worlds, but it is also many other things; and perhaps the best way in which we may arrive quickly at a wider vision—or the best way in which to supplement or complement our broad view by a deep view—is now to turn inwards. We have swept the heavens with the telescope; let us peer into a drop of water with something far more penetrating than any microscope will ever be, and let us see whether we can arrive any more quickly at the inner than at the outer limit of infinite reality. We shall learn that the universe is boundless, not only in greatness, but also in smallness—is not infinite only, but also infinitesimal.

Analysis or anatomy, loosening apart and cutting apart, may be done by the knife or the fingers, up to a point. We may invoke lenses to enable us to see detail, say in the structure of steel or of a snowflake, which the naked eye cannot see. But, indeed, our microscopes and ultra-microscopes take us scarcely any appreciable distance inwards. If we are really meaning to reach the innermost, entirely different methods are necessary, compared with which the microscope and the telescope may almost be called crude; and these methods involve a process which is subtler than sheer seeing, whether it be something under our noses or in the remoteness of the sky. We are compelled to do our separating and identifying of the minutest things by subtle means, and to see the results by the mind's eye alone.

The chemist analyses or loosens apart, as we may analyse or loosen apart a piece of blotting-paper, but he does it with a minuteness which transcends vision, and his description of results must depend on argument and inference. Those who will only believe what they can see—though there are, of course, no such persons, whatever they may fancy, and, if there were, one would reply, with the old Quakeress, "How doest thou know thou hast a brain?"—will answer "Fudge," when the chemist declares his faith in atoms and molecules and electrons, or the physicist his faith in the ether; but we may ignore such persons here. Only we must clearly understand what we are about.

The botanist who describes the structure of a flower is in a happier case than the chemist who describes the structure of an atom; and we and he have to remember that we are inferring and interpreting, not seeing, and that we may require to make a re-interpretation at any moment, which will alter, in kaleidoscopic fashion, the vision which we had formed in our mind's eye. Such a re-interpretation, which goes to the very roots of chemistry and alters half the established notions of ordinary thinking,

has been made necessary in the course of this young century, and has given us entirely new ideas of the inwardness of things. Radium has been the revealer, but we shall never understand what it has revealed until we know how far chemistry had gone before a new epoch was made by this new revelation—so new that Lord Kelvin rejected it to the last.

We shall come later to the chemistry of the skies, but it is necessary here to allude to that question because of a reasonable and important objection which the thoughtful student will here interpose. We propose to study a drop of water in our study of the universe. But "how on earth" do we know that this matter of water is more than a matter of earth—and Mars perhaps, which is near the earth? What right have we to suppose that in studying a drop of water we are studying "universal things"? To this the brief reply is that chemistry finds the heavens and the earth to be made of the same stuff. By a sequence of wonderful inquiries and inventions, the chemists, working in conjunction with astronomers, have found that the materials which make up the earth make up also the heavenly bodies. Scarcely any materials whatever have yet been found in the sky which we do not know on earth.

The Flower in the Crannied Wall that holds the Secret of the Universe

Even when chemists find a new kind of stuff in the sun, and call it helium, a few years later they find it upon the earth as well, so that it might just as well be called terrestrium.

Every possible mode of inquiry, affording copious and varied evidence, assures us that in studying a drop of water, or any other specimen of our world, we are studying "universal things," no less than if we had specimens of Sirius, Jupiter, and Halley's Comet under our fingers. The notion that the study of familiar daily objects is a "parish-pump" kind of science, unworthy of great minds—such as ours!—is on a par with the notion of politics which laughs at the parish pump, as if water-supply were not a matter of life and death to citizens, and therefore to a nation. Tennyson declared that if he could wholly know the flower in the crannied wall, he would know "what God and man is." Well, the chemist is assured that if he could wholly understand a drop of water, he would know the origin and destiny of all things, and hold the key to every happening.

The drop of water may first be studied by the microscope, which will detect dust and microbes and other things which are not water. If these things be removed, the microscope can help us no more, except for its clearer demonstration of the forms of frozen water—ice, hail, and snow. The limit of seeing has been reached.

Here the chemist comes and tells us that the water is still impure, because all manner of gases, obtained from the air, are dissolved in it. It may look very flat to our eyes, but the chemist knows it is still aerated. However, perhaps the gases can be removed, and now we have, at last, a really pure specimen of distilled water—water that is therefore gasless—to study.

The "Treacherous Element" which is not an Element at all

This appears to be so simple and unchangeable a thing that we call it an element—"the treacherous element," "the mercy of the elements"—to this day, as Aristotle did more than two thousand years ago. The chemist, notwithstanding, proves to us that we are wrong, and that water is made of two things, not two fluids, as we should expect, but two gases, neither of them in the least like water. These gases, oxygen and hydrogen—hydrogen meaning watermaker—the chemist calls elements, and he assures us that water is not an element at all, nor even a mere mixture of elements, but that it is a specially constructed compound of the two elements in question. These two, however, and many others, are really elements, he declares.

All this involves a great deal of discussion and experiment, and we are for the present merely outlining it, on our way to what is our new and special concern.

Eighty Things combining in a Million Ways to make the World

We observe only that the chemist describes and names some eighty different kinds of stuff, including oxygen and hydrogen, which he calls elements; and declares that the earth, in all its variety of light and heavy, gas, liquid and solid, black and white, metal and mineral, even also the bodies of all living things, are made up of these elements, either existing unmated with each other, or combined in a thousand—say, rather, in a million—ways to form compounds, of which water is almost as simple an illustration as can be. The astronomer declares that this view, which chemists first alleged of the earth, is true wherever the telescope and its allies can peer. It follows that we must push our studies in this inward direction as deeply as ever we can; and if we go deep here, we are also going deep everywhere.

If we can obtain a specimen of an element by itself—oxygen, gold, or any other—we find, say the chemists, that it is made up of a number of tiny units called atoms. All the atoms of any element are the same, and they are always the same; while, of course, the atoms of any element are different from those of any other element. Indeed, the reason why gold is gold and not iodine is that its atoms are gold-atoms, and those of iodine are iodine-atoms.

Further, a vast part of the power and activity of the world, and of living things, is due to the way in which atoms of one element will unite with those of another, making compounds like water, or iodide of gold, which is formed when iodine-atoms link up with gold-atoms. This power or energy is called chemical energy, and it is what we obtain in all the processes of burning, whether fuel in a power-station for electricity, or food in our hearts for life. And all this—as we must observe now, or we are lost—is what happens *between* the atoms. Not a word of *within*.

A DROP OF WATER FROM A POND
As it is seen under the microscope

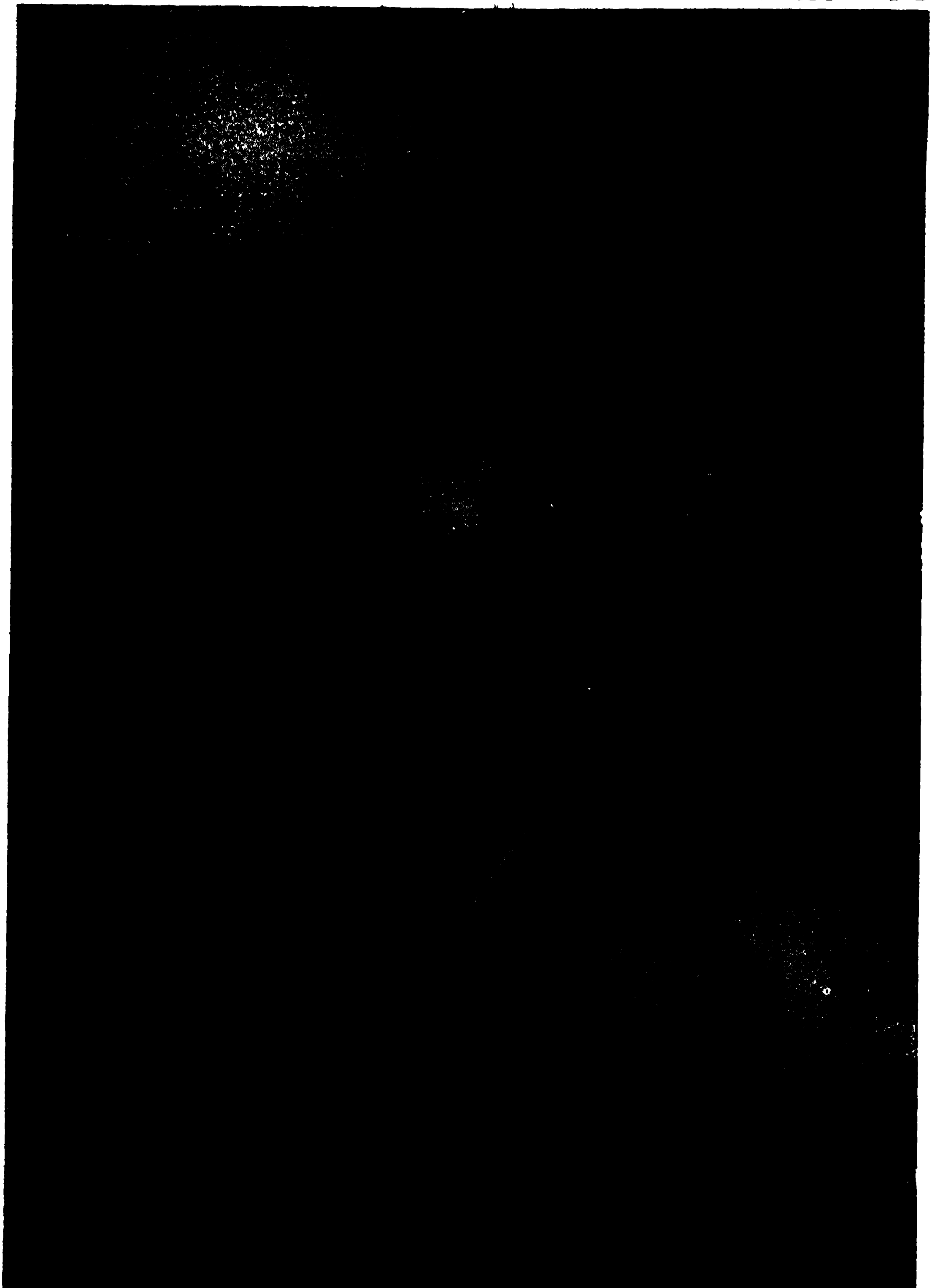
So far chemistry had reached; and this is the accepted chemistry of the schools and the text-books to-day, perfectly true so far as it goes. But the instant we suppose it to go farther than it does go, the true becomes false in our hands. And this, unfortunately, is what chemists have done. Only very rare, great men, like Mendeleef among chemists and Herbert Spencer among philosophers, declined to accept the view that gold-atoms and iodine-atoms and oxygen-atoms, and the other eighty-one or so kinds of atoms, have always been what they are, were made as they are, will never be anything else, "the foundation-stones of the material universe, which have existed from the creation, unbroken and unworn."

To us, to-day, these words, from the latter part of the nineteenth century, sound as remote as if not Scottish but Athenian lips had uttered them. And it is by the light of radium the revealer that we have been enabled to lay the atom—that is to say, the *not-cut*—upon the dissecting-table, and subject it to our anatomy, its proud name notwithstanding. This is an achievement of the first order in itself, and will occupy other pages of this work; here it concerns us not from the point of view of the chemist or the student of electricity, but because it lifts a veil hitherto impenetrable, and ushers us faster than ever heretofore towards the inwardness of things. A space-penetrating telescope, which would dwarf the best now existing as that dwarfs Galileo's, would not extend our ideas of the universe to any appreciable extent, compared with this revelation of the heart of the atom. That may seem a hard saying, but it is true. We know that there are always more and more stars, farther and farther away. We have accepted that idea. Once we have done so, however much we prize bigger telescopes, and however much they reveal to us, they can never reach the limits of our idea, which is itself limitless, for it is the idea of an infinitely extended universe.

THE DISCOVERERS OF RADIUM—M. CURIE AND HIS WIFE

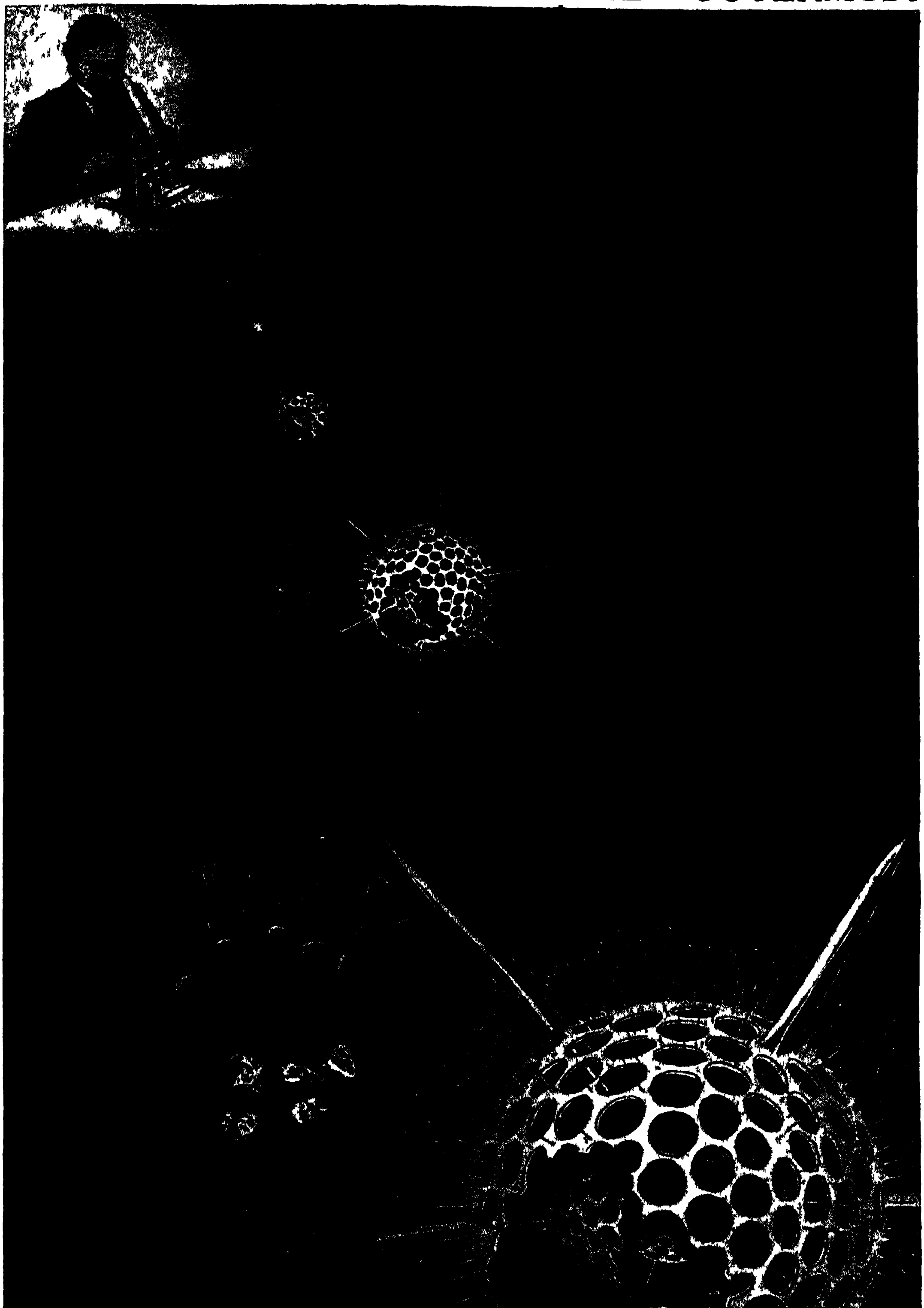
But the discovery which has enabled us to see deeper than the atom, to pierce to the inwardness of the universe, not only

THE BOUNDLESS UNIVERSE—AS FAR TO



THE WONDER OF GREAT AND LITTLE—THE WORLD THAT LIES BEYOND THE

The universe is boundless in great and in little beyond the senses of man lies a vastness of wonder incomprehensible to the human mind. This picture shows a man looking through a telescope at the dot of light just beyond the lens—all that he can see with his naked eye. The increased power of the telescope reveals the clusters beyond; and the most powerful lens shows the great cluster in Hercules, so distant that, while light would reach earth from Mars in three minutes, the light of these stars takes thousands of years.



REACH OF THE TELESCOPE AND BEYOND THE DEPTH OF THE MICROSCOPE

This picture shows a man looking at the spot near the microscope—all that his naked eye can see. The microscope enlarges it and reveals a second spot, and a still higher power reveals a little creature of the sea, a radiolarian, while the second spot appears as a smear of blood. As the power is increased, the radiolarian grows in size and wonder, cells of the blood appear, and microbes come into view, until the full power of the microscope is reached, revealing a world of wonder equalled only, perhaps, by the wonder still beyond.

as we could never do before, but as we did not know was to be done—that discovery enriches our minds with an idea of the universe which is no less precious, and no less necessary in our essay towards completed truth than the work of Copernicus and the idea of Bruno. If we doubt it, let us proceed. No matter whose good guidance we follow, no matter what the penetration and courage of our minds, we shall ere long find ourselves lost, baffled, peering into the beyond; no less than ever did the straining eyes of the astronomer, and with far less prospect of future triumph. The astronomer may always hope for a bigger telescope, a finer lens, a more sensitive camera, but when we have peered our deepest into the atom we shall realise that our next need is of bigger minds; and in this strait the beneficence of Lick and Yerkes and Carnegie is of no avail.

Radium led the way in perfectly straightforward fashion. We have seen that power and energy, such as light and heat, are commonly obtained from combination between atoms, as when carbon is burnt in oxygen; and we might have added that they must always be obtained from somewhere. Radium produced light and heat, and produced light and heat continuously, not to mention here its production of many other things.

The Idea that Radium caught up the Force of the Air and used it

Now, the great chemists who first discovered radium proved that it is an element. It is made up of radium-atoms, as carbon is made up of carbon-atoms. But a piece of carbon, left alone, produces nothing: we get light and heat only when we burn it. Radium, left alone, produces an unimaginable quantity of energy of various kinds for as long as we choose to watch it, and seems none the poorer. The problem is like that which faced Moses in the Bible story of the burning bush, which gave forth light and heat, and was not consumed.

But anything may give forth light and heat by simply reflecting them; and radium might be doing this in a less direct way. The air is always in motion. Its atoms fly about at great speeds in all directions, however still it may appear to us. Radium might be so made that it could take up the force of the atoms of air which hit it, and turn the force into light and heat. This was an excellent idea, and certainly had to be disposed of before we could believe anything less probable. But it was disposed of. Experiment showed that radium went its course, and did its deeds at its own pace, without reference to any changes in the pressure or temperature or quality of the gases to which it was exposed. Its force came from within. People suppose, similarly, that outside forces, happily arranged, push upon people and make them into geniuses.

Radium, the Genius among the Elements, Revealing to us the Atom

But they do not. The genius gets his force from within; and the difference between him and other people is that he was born different. Just so are the atoms of radium born different from the atoms of carbon; and just so, as we have lately learnt, to the astonishment of every chemist in the world, do they get their power from within themselves. Radium is the genius among the elements; and the best service of its genius is the familiar one of throwing light on other and common things, making us understand everyday atoms as Shakespeare makes us understand everyday people such as ourselves.

The property of radium, by which it produces radiance and other things from within itself, is called radio-activity—a clumsy name which is to be learnt because it is now one of the most important names in science. For, indeed, the first fact we discover about this radio-activity is that, when carefully looked for, it is to be found, in greater or less degree, practically everywhere. We may argue that this is due to minute traces of radium being almost everywhere, and that is largely the explanation. But the whole explanation includes the discovery that the atom of radium is not unique in its powers, though unique in their extent.

The Complex and Powerful Forces locked up within all Atoms

In a word, atoms are not atoms, but are complicated structures—some more so, like those of radium; others less so, like those of hydrogen—which have been built up or constructed by the action of powerful forces, and those forces are within all existing atoms now. To some considerable extent they can be measured, and the measurement provides us with an almost incredible result. The forces of the universe known hitherto, such as those produced by chemical union between atoms, those produced by the action of gravitation, all the forces of visible motion of all kinds, and of what is called molecular motion—the motion of molecules, or groups of atoms,

in a gas, or elsewhere—the forces, too, produced by magnetism, and the force of heat and of light, and of other forms of "radiant energy," as it is called: all these are eclipsed, surpassed, ranked as trifling, by the discovery of a source of energy which was wholly unknown until the other day.

The atom, which we thought of as played upon from without, but itself stable, stolid, as we think of a grain of sand, is indeed the reservoir of by far the greater part of the powers of the universe. This intra-atomic energy, contained *within* the atoms, and not derived by action between them, transcends all other known forms of energy put together; and its sensational discovery marks a new age in the history of our understanding of the universe.

We have thus already been taught by radium a lesson which is not unworthy to compare with the lessons of astronomy, though much more is yet to follow. Astronomy has taken old ideas of the world, with the earth as the centre of all things, and the heavenly bodies as its attendants—which could even be arrested in their movement in order that the task of killing all one's enemies after a successful battle might be completed!—and has given us a new idea of the size of the universe by teaching us that ours is one of a company of worlds. The modern study of radium, of radio-activity, and of intra-atomic energy has done no less for our notions of the power of the universe.

THE WONDER BEYOND OUR EYES
The architecture of a snowflake

We have marvelled at the force of explosions, at the motions of the "flying stars," at the "crash of worlds," at the speed of light, and the transformations effected by heat; and, now we learn that these are nothing compared with forces which we had never even suspected to exist.

But, indeed, this is not merely a question of how we conceive the universe and its resources, though, indeed, we do well to realise, as few students of these new subjects have yet done, the full magnitude and significance for our world-view of what radium the revealer has made plain. It is much more, however, than a new idea of a universe: it is a matter of business, of practical politics, of bread-and-butter.

Mankind lives by the consumption of power. We dig up "certain black stones" from the earth, burn them, and live on the power we get from them. We plant fields with corn, which catches the power of the sunlight, and we live on it.

And always we want more power. "Cheap sources of power" are ever the need. "Could we not harness the tides?" "Why not drive machinery by trapping sunlight?" "What a pity we have so few waterfalls in this country!" And so on. Indeed, we feel that if only we could get unlimited power for nothing the millennium would have come. Our trams and trains and motors, our mills and printing-presses, our heat radiators and smelting-furnaces, and all the rest of our devices for

using power, would cost almost nothing, and we could go forward to higher standards of civilisation, or could hugely increase our population, or might even achieve both of these ends.

Radium and radio-activity tell us that practically unlimited power, of high intensity, costing practically nothing, is in our hands—*literally in our hands*, even if they grasp nothing but atoms of air—could we only find how to get at it. If only we could put a torch to an atom, or send an electric spark through it, and get it to explode, as we send a spark through the source of power—a mixture of air and petrol—in our motor engines, we need none of us do any more work worth mentioning to the end of our days, or might confidently set ourselves to do things so stupendous that man has never yet dreamed of them.

Already radium has been harnessed, by the Hon. R. J. Strutt, Lord Rayleigh's son and heir, in such a fashion as to drive a clock; and if the materials of the clock would endure, the radium would drive it for thousands of years. But radium is exceedingly scarce and expensive, and it differs from clay or sand or air or any cheap kind of matter in that its atoms are always exploding on their own account.

Who will look at Coal when Men unlock the Atom?

When we try to hasten or retard them, we fail; and when we try to hasten the rate of atomic explosion in other substances whose rate is exceedingly slow, we find that we fail also. All the power we need is there, and far more, but it is locked up in the safe of the atom, and no one yet knows the combination, and no one has yet forged the key which will turn the lock.

In the physical laboratories of the civilised world at the present time, from the most justly famous of them all, which is the Cavendish Laboratory at Cambridge, down to the humble rooms of private students, men are working devotedly at the solution of this one problem—how to tap the resources of the atom. The solution will come some day; it may be this year; it can scarcely be delayed for more than a century; and when it comes it will utterly transform all human economics and all present adjustments and balances between industry and industry. When it comes, for instance, who but the curator of a geological museum would look at coal for any purpose?

Such is the revelation and such the prophecy of radium, so far as the energy of the universe is concerned, but energy will not be lacking from these chapters till the tale of them is complete, and here our immediate concern is less with the energy which holds together the atom of radium—or any other kind of atom—than with the minute structure which is now revealed.

Like a Full-stop from this Page flying about in St. Paul's Cathedral

The atom has parts, even separable parts; it has an architecture, like St. Paul's Cathedral. It has been estimated that the size of its constituent parts, compared with the size of the atomic building itself, is like the size of a printer's full-stop flying about in St. Paul's. So that an atom, we must observe, is really a dynamic building, and its constituent parts, so far from being laid in their places, never to move therefrom, are in active motion all the time.

But we are passing into the inwardness of things with little appreciation of the length of our journey. Lord Kelvin estimated that if we could magnify a drop of water to the size of the earth, its constituent atoms would be of a size somewhere between that of small shot and cricket-balls. We must seriously try to imagine the number of marbles, say, in a sphere as big as the earth; and then we may feebly conceive of the minuteness of the atoms that compose a drop of water. When we have accomplished this impossible feat, we may think that we have done well, and, indeed, when Lord Kelvin made his comparison, he was seeking to show how minute were the minutest of all things, those atomic ultimates beyond which we could not go. But the twentieth century places any one of these inconceivably minute ultimates — so-called — before its mind's eye, and asks us to regard it as itself a relatively huge structure, composed of more ultimate ultimates, which bear to it the proportion of a pin's head to St. Paul's Cathedral. It is evidently farther to the innermost than we supposed.

A Solar System of Wonder packed into each tiny Atom

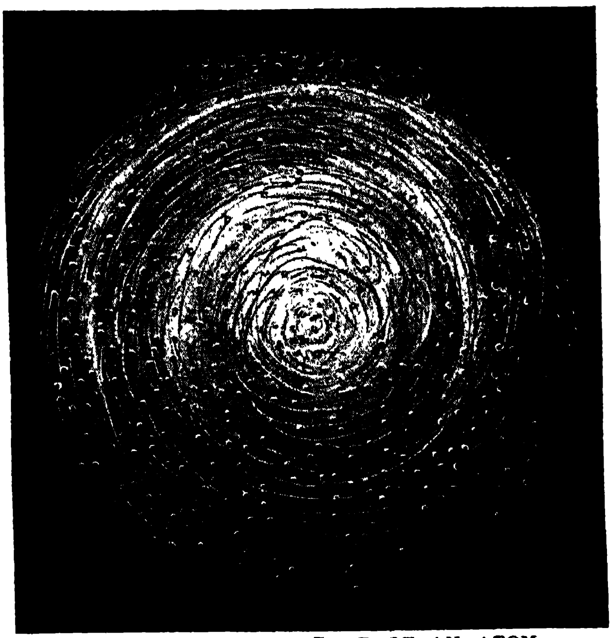
And, indeed, a recent comparison, which is probably much more than a mere comparison, and expresses something like the facts of the atom, helps us to see the justice of the view that our inward journey into things is just as far as our outward journey was. There is good reason to compare an atom not to St. Paul's Cathedral merely, but to such a structure as the solar system, with its central sun and its

attendant planets ever flying thereabout, kept in their places by a force of attraction which runs between each of them and the sun. These planets are, of course, very tiny compared with the distances between themselves.

The earth, a few thousand miles across, is scores of millions of miles from its nearest planetary neighbour; and if we go farther outwards from the sun we find that the distances between planets run into hundreds of millions of miles. The mean distance of Uranus from the sun is 1780 millions of miles, and its outer neighbour, Neptune, is a thousand millions beyond it.

And now the chemists and the physicists tell us that in the atomic system the planets, so to call them, are relatively as far apart from each other as the planets of the solar system. Our journey, therefore, to the central sun of the atom—if such, as is probable, there be—is no mean feat, since we begin outside the atom altogether. It is like the journey of a comet which enters the solar system and travels all the distance from Neptune to the sun before its work is done.

Our work is not done. We have entered the atom in bold and cometary style, and found it spacious and marvellous. As we approach the atomic sun our rate of progress quickens, as a comet's would, but we have not reached it yet. Indeed, we are much preoccupied with the bodies we meet on our way—as a comet may become preoccupied with Jupiter's attraction, and never reach the sun at all. These bodies we meet on the way have such amazing properties, so utterly out of proportion to their tiny size, and are yet so elusive and insubstantial when we try to grasp them in the mind's hand, that they may well occupy us for years to come.

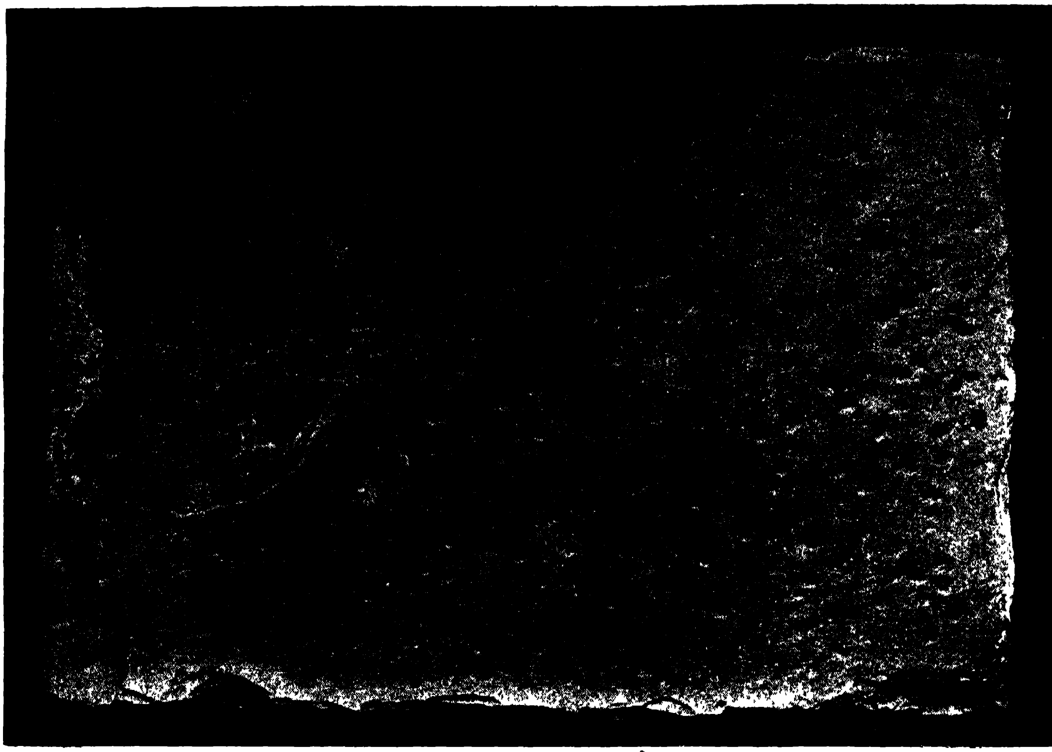


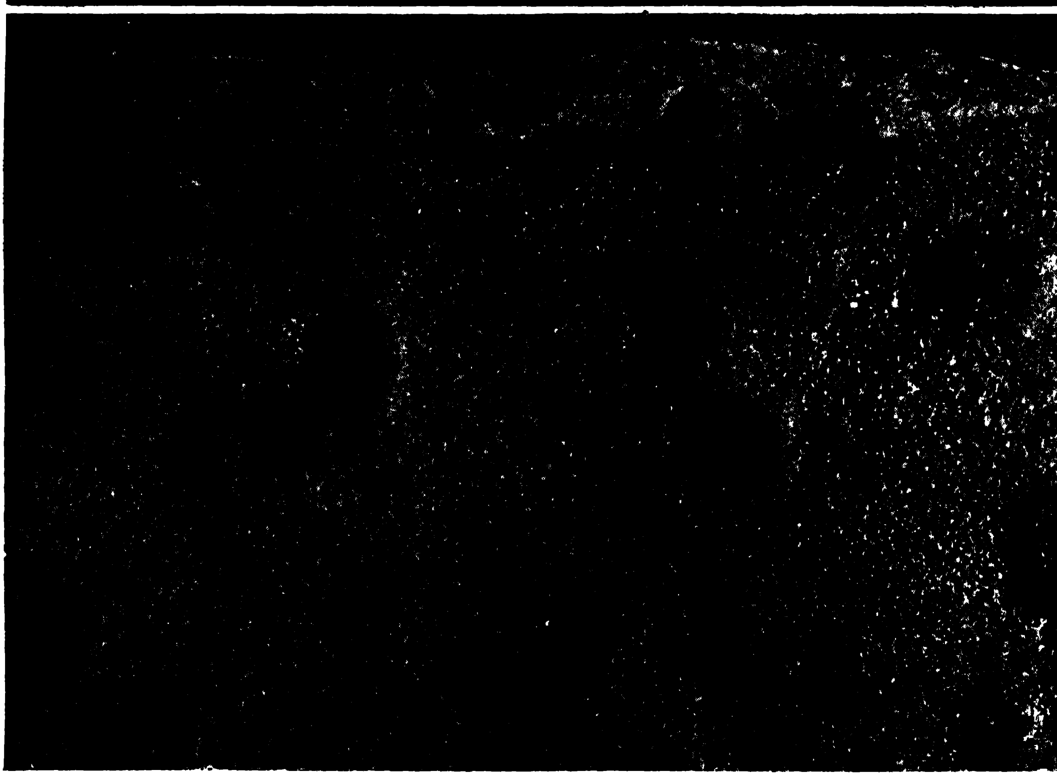
AN IMAGINARY PICTURE OF AN ATOM

No longer is it believed that the atom is the foundation-stone of the material universe, unbroken and unworn from the Creation; for we know now that the atom has within it an uncountable host of smaller structures, flying about within it for ages, with such potentiality of power that it is said that, if we could only unlock it, the atom could do all the work of the world.

These real atoms within the atom, of which much more must be said in these pages, are called electrons. They move in their orbits inside the atom with amazing speed, compared with which the speed of a flying star is almost nothing. These move at the rate of scores of thousands of miles in a single second. They each carry a charge of what is called negative electricity, and it is probable that, while each repels all the rest—which is just the opposite of what happens among the planets of the solar system—they are held together by common attraction to a centre of some kind, which has a charge of positive electricity. When this bond partly or wholly breaks the electrons are released, as when radium atoms explode, and the atom breaks into smaller pieces. The energy within the atom is therefore electrical, belonging to the same order as the electrical energy that we know, but its total amount beggars our imagining.

When we examine these electrons we find that their attributes are all immaterial. They are not gross, palpable, substantial things at all. They are atoms of electricity, and electricity is not a material thing. So far as the evidence at present goes, it would seem that the atoms of matter are themselves made of electricity, and electricity is a form of energy. Pierce we ever so far in our inward journey, we encounter the infinite. Solid forms melt at our touch, the material becomes immaterial, matter becomes energy, and though atoms are formed, and "live" a while, and then "die," energy remains. The things which are seen are temporal, and the things which are not seen are eternal. Whether outwards or inwards, we encounter evidence of an "Infinite and Eternal Energy from which all things proceed"—the vesture and the deeds of what we can only call Deity.





RAINDROPS PRINTED ON SANDSTONE MILLIONS OF YEARS AGO—THE LOWER ONES NATURAL SIZE

These two photographs show the marks of rain that fell in days before history began. The raindrops imprinted themselves clearly on sun-dried flats of mud by the sea, and on the return of the tide the impressions were covered by sediment, which preserved them, sealing them up in the slowly forming rock.

ALL THE WORLD ON FIRE

The Crust of the Earth—How Hard We Know it is, How Thick We Guess it is, and How Old We Think it is

HOW LONG HAS THE EARTH BEEN SPINNING?

THE earth, as we know, was at one time a hot molten mass. It is easy to picture the world in its present solid state, but it is difficult to imagine it a globe of surging, seething, molten metal.

At first there would be no crust. At first the whole surface of the world would be sea. And what a sea! Not a sea of blue water with a fringe of surf rolling in upon yellow sands, not a sea bearing white-winged ships on its bosom, but a seething storm of boiling, steaming lavas, pounded into monstrous waves by tempests of ponderous metallic vapours, whipped into fiery foam by the knout of iron sleet, scourged and scarred by the lash of the masses like stars.

Heavy would be this primeval sea, and there would be no moon to move it, but the sun would drag and churn it, and the atmosphere—which then must have exerted a pressure of 5000 pounds to the square inch, instead of sixteen pounds to the square inch as now—would plough and furrow it. There would be currents between the poles and the equator, for the cooler metal at the poles would sink, and warmer molten metal from the equator would flow in. No doubt cyclones and anticyclones would also arise, and drive before them the molten mass.

Over this weird wild sea unbroken night would reign, for the sun would be hidden by the heavy metallic vapours, and the only light would be the flashlight of the shooting stars, the glow of the fiery waves, and the flicker of the terrible primeval lightning. The rumble of the thunder, the thud of the ponderous billows, the splutter of the molten hail, the roar of the metallic tempests, the sizzle of the falling stars, would create a perfect pandemonium. Such a Hades heat can make!

But heat is ephemeral; every hot body cools, whether it be a hot potato, or an incandescent fire-mist, or a glowing world. Age after age, heat radiated into space, and as it radiated away the great earth-cauldron ceased to boil, and began to simmer. Cool currents fell, hot currents rose in the bubbling mass, and by-and-by, even as rough ice forms on a freezing lake on a windy day, so a wind-roughened crust began to form on the surface of the molten, steaming sea.

At this time almost all the water now in the sea would be in the atmosphere. A shell of water about two miles high would be spread through the air, and would exercise a tremendous pressure on the surface of the globe—a pressure equal to solid rock 4000 feet thick. Accordingly, since pressure assists the consolidation of molten masses, the crust would begin to solidify at a very high temperature, probably a good deal over 2000 degrees Fahrenheit. Under such pressure, and beneath such a blanket of hot, damp air, cooling would proceed very slowly; but as the crust cooled it would contract, and the contraction again would cause strain. And the crust would be exposed to other strains.

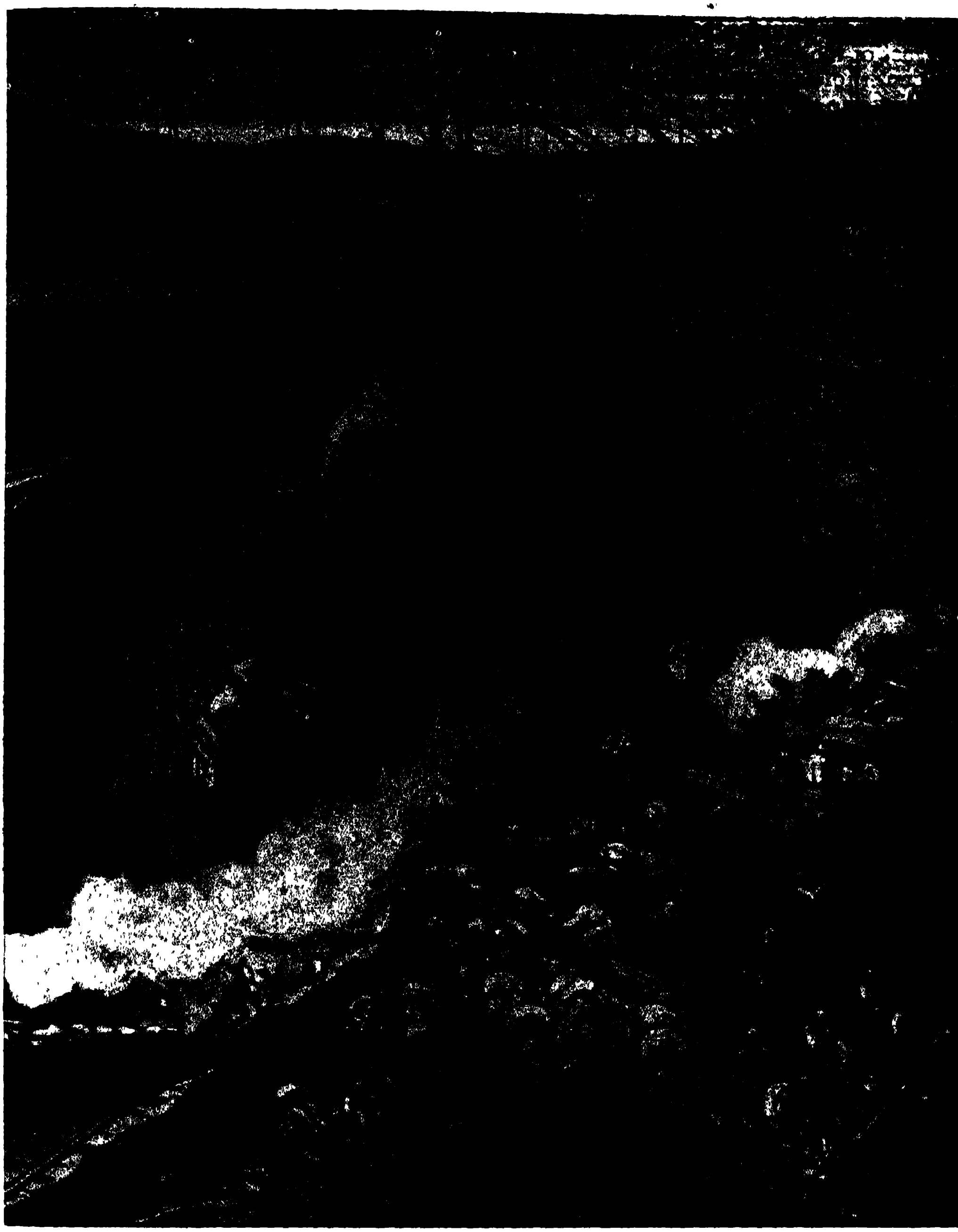
It would be tugged by the sun and moon —supposing that the moon had come into existence then—and battered by the heavy atmosphere, and underneath it the hot liquid tides would surge and heave. Under such strain the crust would crumple and rumble, and quiver and boom, and finally there would be an earthquake and a volcanic eruption, and the crust would crack and crash like broken ice on a river in a thaw, its fragments floating on the steaming sea beneath. Again and again, no doubt, the crust would form; again and again it would crack. It would be a time of earthquakes and volcanoes, of "glutted hell disgorging fiery spume." But by degrees the crust would grow stronger and stronger,

THE EXTRAORDINARY CONCEPTION OF M. FLAMMARION, THE FRENCH ASTRONOMER, TO BORE A

A distinguished French scientist with great imagination, M. Camille Flammarion, has suggested an amazing scheme for investigating the real nature of the interior of the earth. The deepest hole ever bored in the earth is just over a mile deep, but M. Flammarion suggests boring nearly five miles down. This huge cavern, with a diameter of nearly a quarter of a mile, would take many years to

and ultimately it would be strong enough to endure the strain of contraction. Then the earth would show an irregular surface, roughened and indented by the marks of many scars and of many badly set fractures.

As the cooling still continued, the water in the atmosphere would condense, and hot rains would deluge the world. As the world would then be much hotter than the rain, the rain would hiss as it fell, and would evaporate rapidly. But the rapid evaporation would hasten cooling, and in time permanent pools would form. What a momentous event the first little puddle



HOLE FIVE MILES DEEP AND 350 YARDS WIDE, FOR STUDYING THE INSIDE OF THE EARTH

dig and would cost millions of money, but M. Flammarion suggests that it would be a scientific work upon which parts of the standing armies of the world might well be engaged. These pictures convey an artist's impression of the scene while the work is going on as M. Flammarion imagines it, showing the enormous cranes and "grab-buckets" which would run down into the earth to bring up the broken rocks.

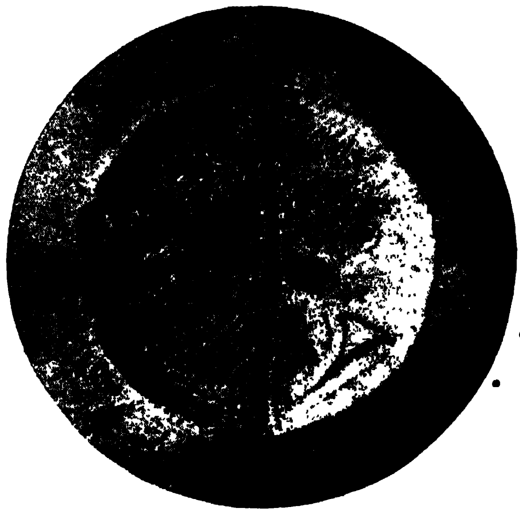
was! Who could have foreseen in it the mighty oceans of the world?

That the earth has now a solid and stable crust is self-evident. Sometimes it yawns and swallows an island; sometimes it shudders and shakes down a city, but, as a rule, it is certainly *terra firma*. When, however, we come to the question of what is below the crust we reach more debatable ground, and find much difference of opinion. Indeed, it is almost impossible to decide whether the central mass of the earth is molten or solid. Let us look at some of the facts concerning this question.

When we examine the temperature of the crust of the earth, we find that down to the depth of a hundred feet it varies according to the amount of heat it receives from the sun, and that at a depth of a hundred feet, just beyond the reach of solar heat, it retains a constant temperature of 52 degrees Fahrenheit. So far there is no suggestion of a hot interior. But when we penetrate deeper than a hundred feet we find that the temperature of the crust rises. The rate of the rise depends, to some extent, on the conductivity and chemical character of the rock, but, in general, borings show a more or less regular increase of temperature with increase of depth.

Of course, men have never bored far. One of the deepest boreholes ever made was made by a German engineer, Captain Huyssen, who drilled a hole no less than one mile and 117 yards deep—a hole, that is to say, twelve hundred feet deeper than the height of Ben Nevis. A still deeper hole was bored in Upper Silesia, measuring 2190 yards. That sounds like a deep hole, but it is really only a pin-prick in the earth's skin, for it is nearly four thousand miles from the surface to the centre of the earth.

Captain Huyssen bored the hole in search of coal, but he had sufficient scientific curiosity to test the heat at different depths, and he found that for each sixty-six feet of descent—below the level of solar heating—the temperature increased one degree Fahrenheit—that is, at the rate of 80 degrees Fahrenheit per mile. Some other experiments have shown that there are many exceptions to this rule, but it is generally established that the temperature increases at the rate of one degree for every 50 to 60 feet descent into the crust of the earth.



AN AMAZING EFFECT OF PRESSURE

So great is the pressure of the earth that clay 1000 miles deep must be as heavy as iron, and ten miles down the pressure equals the force of the explosion in a 110-ton gun. This picture shows how a piece of soft moss penetrated into steel under the pressure of gun-fire, a cartridge having been fired immediately above it.

Between our feet and hot rock, then, is only a comparatively thin film of cool crust. Peel only two miles of rock off the surface of the world—a layer less in proportion to the mass of the world than its skin to the mass of an apple—and we should all be grilled. This is a remarkable fact, but facts still more remarkable follow. If the temperature of the rock thus increases, the heat must be flowing from still hotter rock deeper down, and we may conclude that even at greater depths the heat continues to rise, though perhaps not so fast as in the upper layers. We are constrained, therefore, to believe that the earth is still intensely hot in its interior—hot enough at fifty miles deep to fuse or to volatilise the most refractory rocks. Deeper still, the heat must become terrific. We may assume, then, that the earth still hoards in its interior a huge store of the tremendous nebular heat with which it is believed to have started. Strangely enough, however, even assuming this, we cannot venture to assert that the core of the world is molten. Pressure tends to solidify, and the core of the earth is under enormous pressure. Not only is it squeezed, as in a vice, by the contraction of the cooling surface layer, but it is compressed more and more under the load of superincumbent rock. So great is the pressure in the interior that clay at a thousand miles depth must be as heavy and dense as iron. Ten feet of rock means a pressure of fifteen pounds on the square inch; a mile means three tons a square inch; while ten miles means

HOW WE KNOW THE EARTH IS HARDER THAN STEEL

These lines represent vibrations through the earth and through steel. A tremor passes through the earth the distance of the bottom line in the same time as a tremor passes through steel the shorter distance at the top. As vibrations move more quickly in rigid bodies, this proves that the earth is more rigid than steel.

A SCIENTIST'S PLAN TO PIERCE THE EARTH

AN IMAGINARY PICTURE OF THE BORING OF THE FIVE-MILE DEPTH SUGGESTED BY M. FLAMMARION, THE FAMOUS ASTRONOMER, FOR STUDYING THE INSIDE OF THE EARTH.

a pressure of thirty tons a square inch—a pressure nearly equal to the pressure inside a 100-ton gun when the cordite is exploded. Deep in the interior of the earth the pressure must be many thousands of tons.

So that, though the heat in the heart of the earth is sufficient to melt or reduce to a vapour the most refractory rocks, we have no right to assume that the rocks are actually melted or vapourised, for pressure so prodigious may alter or counteract the effects of the heat. We have to decide, not whether the heat is sufficient to melt or vaporise rocks under laboratory conditions, but whether the heat can melt or vaporise rocks under such conditions of very extraordinary pressure as exist in the earth.

We know that pressure affects the melting-point of substances; we know that, under abnormal conditions of temperature and pressure, matter begins to react in abnormal ways. Potassium under ordinary temperatures rushes about on the surface of the water, tearing oxygen from the water molecules, and setting itself on fire; but, as Professor Dewar has shown, "a berg of silvery potassium might float for ever untarnished on an ocean of liquid oxygen."

The Titanic Forces that Fight for Mastery Inside the Earth

When we exhaust a Crookes tube the attenuated matter left behind acts in quite new ways. Under great pressure steel may be made to flow like butter, and granite pebbles are found flattened like pancakes, yet retaining their crystalline structure.

Novel conditions, therefore, alter the customary behaviour of matter, and here, in the earth's heart, we have most novel and abnormal conditions. We have two titanic antagonistic forces fighting for mastery—we have prodigious pressure tending to keep the rocks solid; we have terrific heat tending to melt and vaporise them. Which force, down in the obscure depths, gains the victory? We cannot say. It is true that the increase in pressure is not so great proportionately as the increase in heat, but that is not sufficient to decide the question; and, so far as the facts of heat and pressure go, the centre of the earth may be either solid or liquid or gaseous: it may even consist of electrons—infinitesimal particles which behave neither as solid, nor liquid, nor gas.

Consideration of the facts of heat and pressure cannot, then, decide the question of the condition of the earth's centre. Nor are other considerations conclusive. We find some facts suggesting solidity. It is certain that the earth behaves as a solid rigid body; it is certain that the crust must be as rigid as steel, for otherwise it would yield to the attraction of the moon, and show tidal waves. Arguing from this fact, some maintain that there must be solid crust reaching at least a thousand miles down in the earth.

The Three Theories as to what the Inside of the Earth is Like

Again, the vibrations that are caused by earthquakes are transmitted as waves both round the superficial crust of the earth and through its substance, and it is known that the vibrations travel through the earth at the rate of ten miles a second. But ten miles a second is faster than vibrations travel through steel, and that proves that the interior of the earth is more rigid than steel. Yet, again, mathematicians have shown that the *precession* of the earth's axis indicates solidity. The *precession* is due to the attraction of the sun and moon on the earth's equatorial bulge, and mathematical reasoning proves that this attraction would probably stagger the earth still more if it had a liquid centre.

On the other hand, it is quite possible that liquid under great pressure might behave like a rigid solid, and the geological phenomena of earthquakes and volcanoes seem to indicate a thin crust. Some maintain that there is a thin crust, a solid nucleus, and an intermediate liquid layer.

Altogether the question is quite undecided; and we may hold with Mr. Hennessy that the crust is only twenty miles thick, or with Professor Huxley that it is about a thousand miles thick, or we may follow Lord Kelvin, who thought the earth to be quite solid.

Is the Nebula from which the Earth Evolved still giving out Heat Inside the Earth?

Whatever the result of the heat may be on the solidity of the earth, it is certain at least that the earth is a great reservoir of heat, and this fact in itself goes far to confirm the theory of the earth's origin from nebulæ. For if the heat be not derived from an incandescent nebula, how are we to account for it?

It is true that the earth once rotated four times faster than it rotates now, that its retarded motion implies friction—such friction as is manifested in the tides—and that friction develops heat just as certainly in a planet as it does in a grindstone. No less than about fifteen-sixteenths of the revolutionary energy of the earth has been thus converted into heat. But heat so pro-

duced would be found chiefly in the superficial layers of the earth, whereas the heat of the earth is focussed in its centre. No doubt frictional heat augmented and augments the native heat of the earth, but in all probability the main source of the earth's heat was the energy of the nebula, though this has probably been re-inforced by the heat produced by radio-active substances.

When we come to consider the earth's age, we derive many hints from its heat.

The Heat which would Melt a Shell of Ice Covering the Surface of the Earth

The earth is still hot, but—if we neglect for the moment the matter of radio-active substances—it is cooler than it used to be, and by estimating its rate of cooling and the degree to which it has now cooled it is possible to get some idea of its age.

As rock and air are both bad conductors, the rate of cooling is comparatively slow, but still cooling goes steadily on; and Professor J. D. Everett estimates that the amount of heat leaking away from the earth every year would suffice to melt a shell of ice an inch thick over the whole surface of the globe. Of course, at varying epochs various circumstances, such as ice on the land and carbonic acid in the air, must have affected the radiation of heat, but still it must have leaked away century after century, and it is possible to calculate in a general way the rate of leakage.

The original heat-energy of the nebula we cannot guess, but as consolidation of the earth's crust probably took place at a temperature of about 2000 degrees Fahrenheit, it is possible roughly to estimate the time that must have elapsed since then. From a calculation of this kind, Lord Kelvin came to the conclusion that the crust of the earth can be only twenty to forty million years old, and more likely twenty than forty, and he corroborated his figures by an estimate of the age of the sun.

The Time it would take to Freeze a White-hot Globe as big as the Sun

The earth is certainly not older than the sun; and the sun cannot have gone on blazing as it does for more than a certain number of years, it, too, must be cooling. A globe of white-hot iron as large as the sun would cool to freezing-point in 48 years; a globe of coal as large as the sun would be burnt out in less than 3000 years; the rain of meteorites which is supposed to stoke the sun cannot have much fuel value, and until Helmholtz suggested that contraction was the main source of its heat the sun could be given only a short life. Helmholtz gave the sun longer life by proving that an annual contraction of sixteen inches would suffice to produce the solar heat. But even if we admit contraction, and suppose that the sun has contracted from an infinite nebula, we cannot give more than four or five hundred million years' life to the sun; and Lord Kelvin concludes that it is, "on the whole, most probable that the sun has not illuminated the earth for one hundred million years, and almost certain that he has not done so for five hundred million." Professor Tait is more niggardly still, and will not admit that the earth has had more than twenty million years of sunlight.

Estimates varying from twenty to five hundred million years are obviously rough, and other plans have been taken to get more exact figures of the earth's age. Certain inferences have been drawn from the tidal retardation of the earth. We know that formerly the earth revolved more rapidly, and that a thousand million years ago it must have revolved twice as fast.

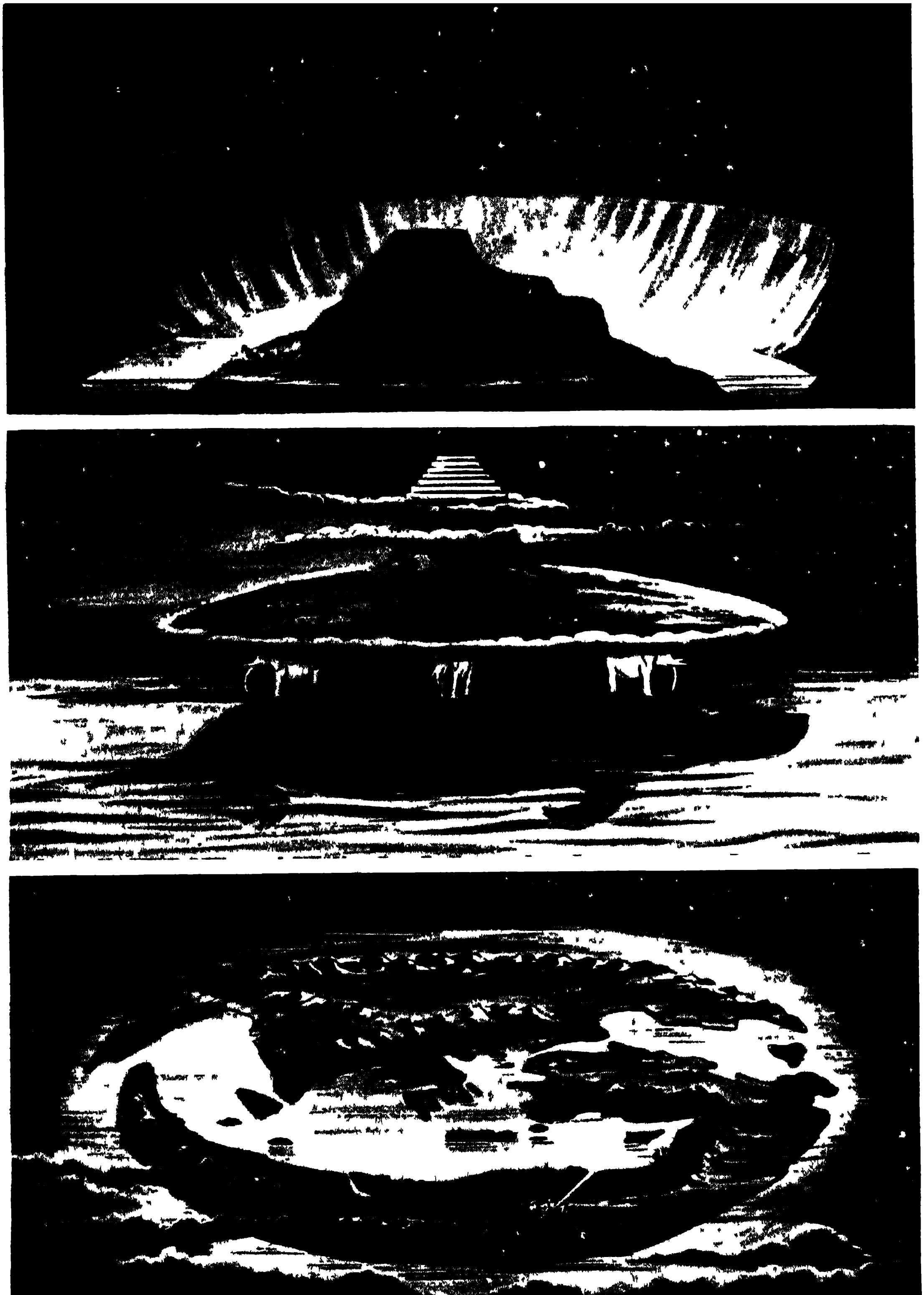
Has the Earth been Spinning for a Hundred Million Years?

Now, if the earth had consolidated when spinning at such a rate, it would have been flatter at the poles and more bulging at the equator than is the case. So, from a consideration of the amount of flattening and bulging, we can estimate the rate of its spinning at the time of consolidation, and from this rate we can fix the date of its consolidation. Working on these lines, most mathematicians fix the date at not more than a hundred million years ago. But this reasoning is not quite sound, since, even if the earth had been more flattened at the time of its consolidation, it would not have been quite rigid at first, and might afterwards have altered its shape to suit the diminishing rate of its revolution.

The age of the earth has also been calculated on geological grounds, by estimating the probable time required for geological processes, such as the accumulation of the sediments produced by rain and streams. We can discover the rate at which land is worn away at present; and as we find great layers of so-called sedimentary rock made from wear-and-tear deposits, and as we know the thickness of the layers we can estimate the length of time the deposition has required.

The total thickness of the sedimentary deposits is about fifty miles. That is a tremendous heap of sediment, more than fifty times the height of Ben Nevis, and about ten times the depth of the deepest sea. Now, it has been estimated that

WHAT THE EARTH WAS THOUGHT TO BE



Long ago, in the early ages of the world, the minds of men reached out into strange places in searching for an explanation of the earth. The Hindus thought the earth was borne by huge

WHAT WE KNOW THE EARTH TO BE

elephants standing on a tortoise swimming on a sea of milk, the Chaldeans thought it an enclosed chamber surrounded by water; and even the wise Greeks thought it a disc floating in a sea

sediment is deposited on the average at the rate of a foot a century, and on such an estimate the earth would be about twenty-six million years old.

But there are many difficulties in the way of getting reliable results from this method. We find that sediment deposits at very different rates, and that it is difficult, also, to estimate the thickness of layers of sediment. It is also known that many layers of sediment have been washed away by the action of the elements. Accordingly, by this method different geologists have attained very different results, varying from twenty million to a hundred million.

How Long have the Rivers Carried Salt into the Sea?

An interesting attempt has been made to estimate the earth's age by calculating the amount of salt in the sea. The sea, having been formed by condensation, was originally pure distilled water. Now the sea contains 144 billion tons of salt—enough salt to cover the whole dry land to the depth of 400 feet. The question is just how long the salt took to collect. Every year the rivers discharge into the ocean 6524 cubic miles of water; and Professor Joly's analysis of the water of nineteen great rivers, discharging 488 cubic miles of water, showed an average of 5·73 salt per million. That means that the rivers discharge about 160 million tons of salt into the sea every year, and at that rate it would require 90 million years to accumulate all the salt now in the sea, and we might set that down as the age of the earth. The data, however, is clearly not quite certain.

By making a similar calculation of the total amount of sediment running into the sea annually, as compared with the total thickness of the sedimentary rocks, the geological age has been computed as eighty million years. We find, accordingly, that geological and mathematical methods have succeeded in calculating the age of the earth only very roughly, and that results varying between twenty million and 140 million years have been obtained.

The Millions of Years that Life may have Needed for Making Men and Women

But even an age of 140 million years has not satisfied the biologists, and they have demanded many million years more, in order to allow for the evolution of living beings. Of late the discovery of radio-active substances, such as uranium and radium, has cast new light on the problem, and has rendered it possible to add millions to the possible years of the earth. Radio-active substances are substances which contain atoms in the act of breaking up, and this breaking up of atoms generates heat. Now, the earth's crust has been found to contain radio-active substances in such quantities that even if they extend only ninety miles down they would suffice to supply all the heat that leaks away from the surface of the earth. It has been found, too, that great heat and great pressure do not affect radio-activity, and that radio-active substances continue to produce heat even at high temperatures. Radium is almost certainly present in the sun as well as in the earth; and it has been calculated that about 3½ grams in each cubic yard of the sun would be enough to supply its heat for thousands of years.

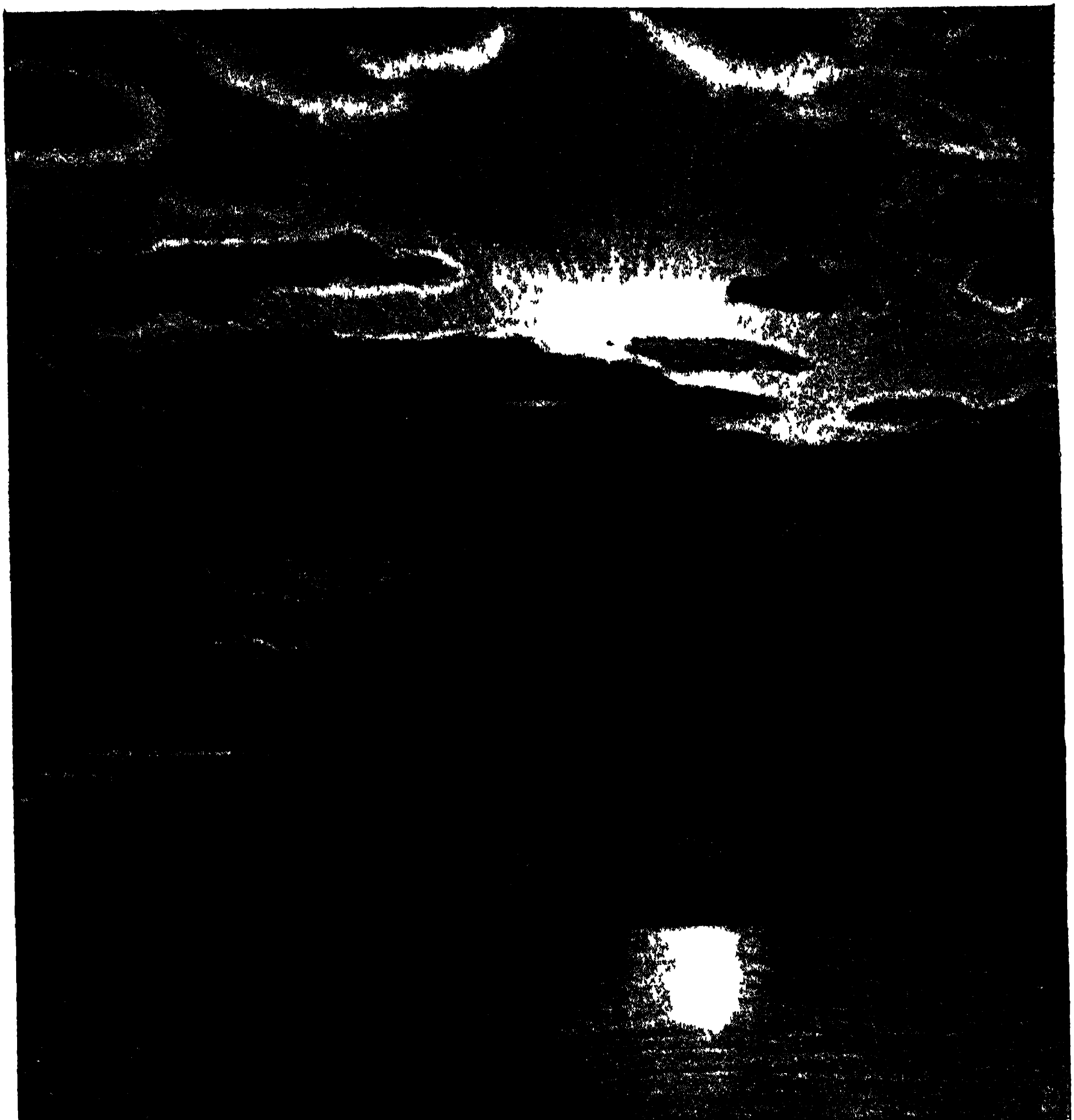
This wonderful discovery of self-heating substances evidently affects all calculations of the earth's age from the facts previously considered, for if one source of the earth's heat be the heat now produced by radio-active substances, and if there be more than enough heat produced in this way to compensate for leakage, the whole problem is widened, and the earth has certainly lived for many more years than the calculations of the mathematicians gave it.

The Fiery Furnace of the Earth that may be Creeping up to the Surface

Not only does it become impossible to estimate the earth's age from the present temperature of its crust, but it is even quite possible that the earth is no longer cooling down at all. Though it may have been losing its heat, yet if there be radio-active substances in the earth's crust and core, then heat is probably accumulating in the deeper layers of the earth, and may ultimately reach its surface and reheat its crust.

It may be asked why the heat in the centre of the earth does not reach the surface at once; but if we consider the distance the heat has to penetrate with the fact that rock is a bad conductor, the reason is plain. Lord Kelvin showed that if the rocks in the earth's interior were as bad conductors as the surface rocks, the earth's core would retain almost all its original heat for a thousand million years; and in the same way the central layers may grow intensely hot, while the surface remains cool, and even grows cooler.

Altogether, the results obtained from these new calculations have led to a belief that the earth is much older than the twenty or forty million years allowed by Lord Kelvin, and have given the biologists many more millions of years for the working



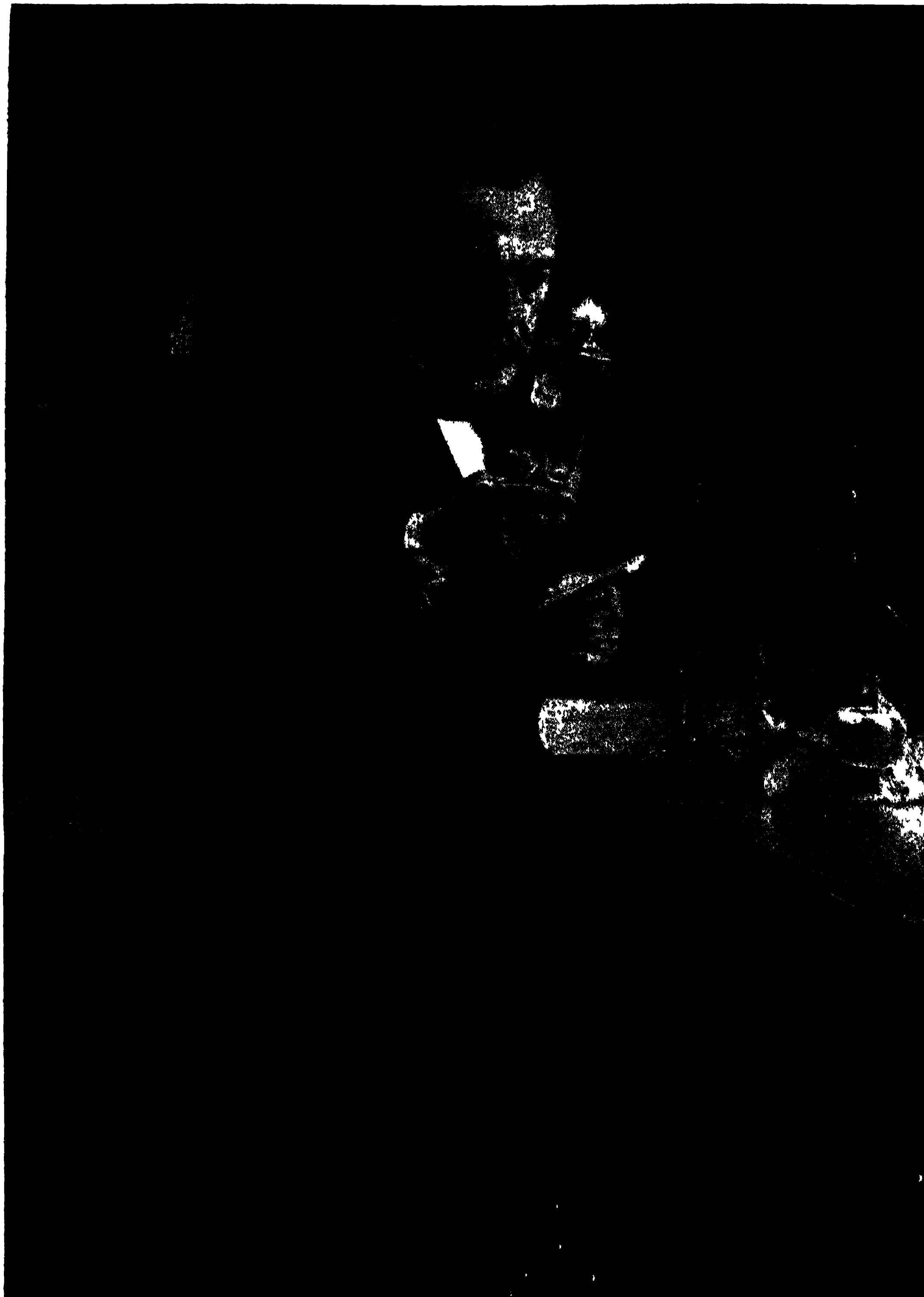
HOW LONG HAS THE SUN BEEN SHINING?

Lord Kelvin thought it probable that the sun had not illumined the earth for a hundred million years, and Professor Tait thinks the earth has had not more than twenty million years of sunlight. Other estimates give the sun a past of five hundred million years.

out of their evolutionary processes. But we cannot say that the age of the earth has been definitely decided, and we must take the figures with a good deal of caution.

What amount of heat is being generated by radio-activity in the centre of the earth we do not know, but it is not improbable that heat is accumulating in the core, and that in a hundred million years or so the earth may be again a molten mass.

Radium suggests a new source of heat for both sun and earth; it allows us to suggest a much longer past for both, and a much hotter future; and it also suggests that there is a smouldering fire in the heart of the world which will eventually consume it. According to this new view of things, if radio-activity exceeds a certain point the earth will become a furnace; and if it fails the earth will gradually become ice-cold, with liquid air lying on the frozen seas. It is strange to think that this mighty globe should be at the mercy of a few decaying atoms, but so, in the light of our new knowledge, it would seem to be. What an instance of the power of the infinitely little over the infinitely great—"the unending flow of energy from unstable atoms wrecking the stability of a world"!



The possibility of the production of life from not-living things was keenly debated by the scientists of the last generation, and Pasteur made up his mind against this possibility after a long series of experiments, which showed that, with all the known materials ready in the test-tubes, no life could be produced.

CAN MEN CREATE LIFE?

The Power which in its Simplest Form is More Amazing than a Man-of-War

WHAT TYNDALL'S EYE OF FAITH COULD SEE

Having surveyed the variety and power and majesty of life, we naturally ask: Where does it come from? A simple, straightforward query, but at present so unanswerable that very few men of science are even trying to answer it, though nothing can be more important. But though no one yet knows where life comes from, and though no one can create even the simplest living thing, we do know a great deal which will help to answer the question some day; and we look at it in a very different light from that will-o'-the-wisp by which our predecessors thought they saw it.

Let us define our problem. Here are all manner of living things upon the earth, animal and vegetable, high and low, mammoth and microbe. One and all they are destined to die. But though all individuals are mortal, life is maintained by reproduction or parenthood. The living things we know, whose production of the next generation we witness in flower and fruit, in kittens and lambs and foals, are themselves the offspring of parents like themselves.

That is one stage of our inquiry. All the living things now upon the earth appear to be the offspring of others like themselves. The origin of the existing life of the planet is therefore to be found simply in the parents of present individuals.

But we must not assume that this is wholly true. Though we are sure that existing children have all had living human parents, are we sure that all existing microbes have had microbic parents? Is it not possible that some of them have arisen by what is called "spontaneous generation" from dirt and water and air and other such materials? We may safely assume previous cats, sheep, human beings, wherever we observe kittens, lambs, babies; but, though we are sure in these cases, we cannot be so sure in the case of microbes, or the amœba of the ponds, or other forms of life which are so small and simple, and seem so easily to make their appearance "from nowhere," that perhaps they do represent a fresh beginning of life from the lifeless.

The critic may reply that he is not really interested in the origin of microbes and amœbæ, which are so insignificant and undistinguished. He wants to know where the great forms of life, noble trees and nobler men, come from; and if he is assured that they always come from ancestors like themselves, he wants to know where the *first* trees and men came from.

At this point we encounter the doctrine of evolution, which makes all the difference in our reply to this critic. If we ask the origin of all or any of the living species which we see around us, and of which our own species is one, we plainly have to choose between two possibilities. Either they each began independently, somehow, as we see them now, or else they have grown or evolved from one another. The doctrine of their independent origin comes to us in this part of the world as the story of the Garden of Eden. It is the doctrine of "special creation," according to which all the forms of animals and plants were created once and for all, as they are now, and have been maintained, to the present day, by the process of parenthood, "like begetting like."

No one now believes in this doctrine of special creation. The slightest thought and study show that the various kinds of animals and plants have somehow evolved from one another, higher forms being developed from simpler ones, and those from simpler still. No evolutionist—and that means no student of the subject to-day—would.

therefore, dream of trying to find the origin of trees or birds except in other forms of life which came before them; and if we continue this line of thought long enough, we come, by necessity, to the humblest and most primitive forms of life that we can discover. When we have reached these most primitive—or *supposed* most primitive—living things, and cannot trace their origin to anything humbler, as we can trace birds to reptiles or men to apes, we are at a standstill. In fact, we have reached the real problem of the origin of life. If we can explain the origin of these humblest things we have evidence which permits us to believe that higher forms of life would follow, and therefore the origin of the lowest form of life is the whole problem.

Thus, when men of science now study and discuss the origin of life it is understood that they are studying the very humblest possible forms of life, and that if they could prove the "spontaneous generation" of the tiniest, rudest, feeblest, living speck from materials in which there had formerly been no life as we understand it, all later developments of the powers of life would have found their key. The question therefore is: Does lifeless matter in any circumstances produce living beings, however humble?

The keenest and bitterest controversy raged over this question a generation ago; a curious historical fact when we observe that it is hardly ever discussed—at least, in this country—to-day, though it is just as important as ever, and even more interesting. The verdict at the time was that lifeless matter never produces life, and therefore that some entirely special and unique cause must have endowed our planet with its first life. The students of the earth report with absolute certainty, on overwhelming evidence, that it was once in such a state of heat, to mention nothing else, that no life could have existed upon it. It is now covered with life; and yet, as was and is asserted, not-living matter cannot yield life!

For some reason which we cannot realise to-day many who joined in that controversy were anxious to exclude any explanation which endowed "Mother Earth" with the power to be a mother at all. They wanted to prove her, not only incapable of evolving new life from the lifeless now, as they asserted, but incapable of ever having done so. These believers in the sterility of the earth, and in the incapacity of what they called "dead matter" to become alive, were hard put to it to invent some other theory. They did invent two. Of these, one was the theory of "special creation" in a slightly different shape, asserting that, though the different forms of living beings were evolved from one another and from simpler forms, the first germs of life were specially created and planted upon the earth, on some unique occasion in the past, by the special interposition of Deity.

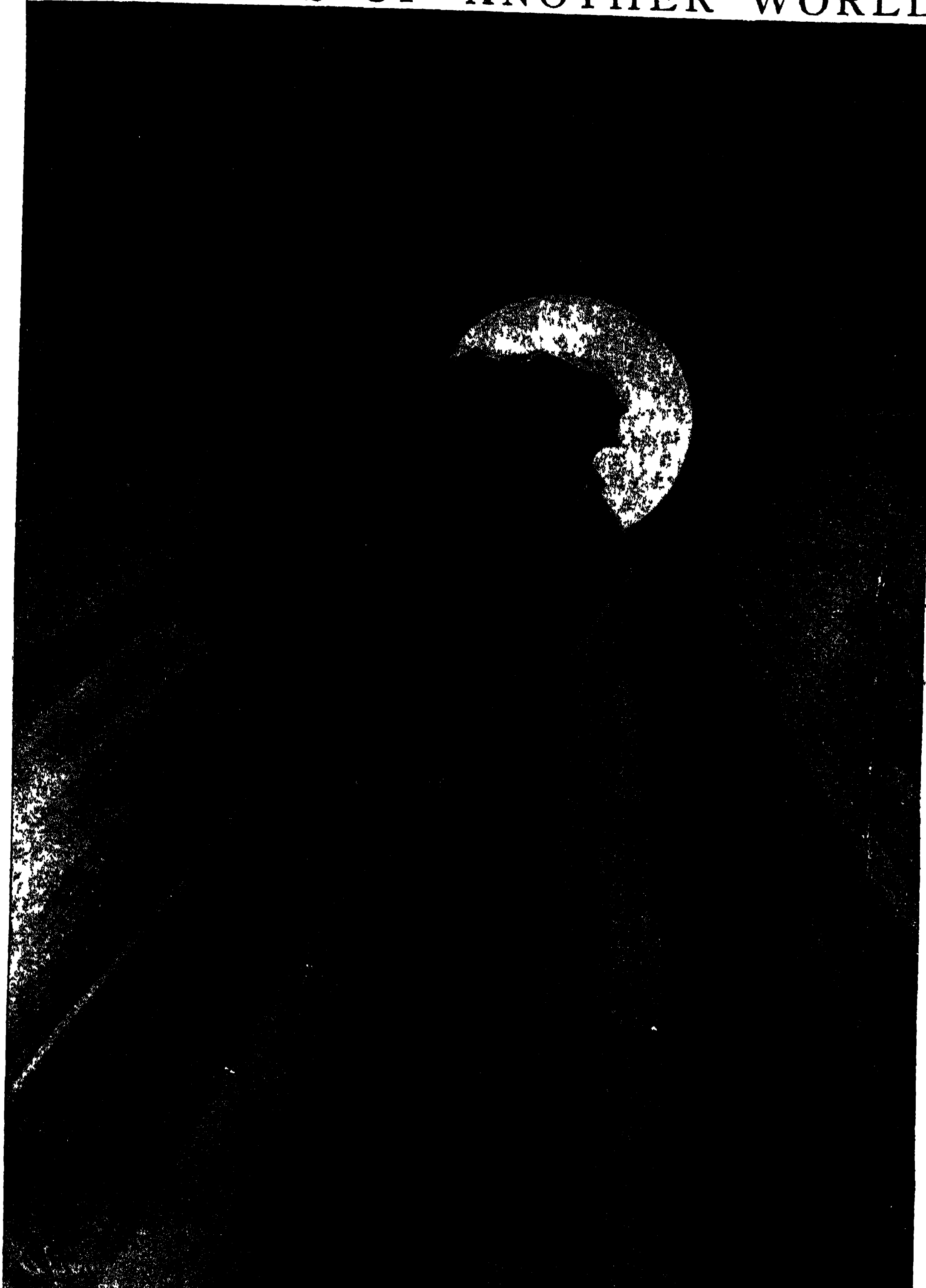
THE ASTOUNDING POWERS OF REPRODUCTION OF THE AMŒBA, THE SIMPLEST CREATURE KNOWN

This series of pictures shows an amœba, the simplest form of animal that we know, reproducing itself as we watch it through the microscope. In the second picture the single nucleus is forming into two; in the third it has definitely become two, and the amœba is elongating itself; in the fourth and fifth the body is breaking up; and at last another amœba is in the world, ready to repeat the process.

This was considered a more reverent and religious view than that which credited Deity with having created atoms and forces so wonderful and so divine that they could engender life from themselves. But we all see nowadays that, of the two views, the newer one is the more reverent and more profound and more religious. Here we need not concern ourselves any more with the old view, which finds no new champions.

The alternative theory held by scientists of this school was a very ingenious and sensational one. They suggested—Lord Kelvin being their leader—that possibly the first germs of life might have been borne to our earth "on the moss-grown ruins of another world." Some older planet, comparable to Mars or Saturn, might have had life upon it, and in the course of its travels might have undergone

THE RUINS OF ANOTHER WORLD



Perhaps the most imaginative theory ever held of the origin of life on the earth was that of Lord Kelvin, who suggested that possibly the first germs of life might have been borne to earth "on the moss-grown ruins of another world," meaning such a planetary fragment as this. The suggestion has in it more imagination than science, but it is significant that it should have come from Lord Kelvin.

a collision with another celestial body, and its "moss-grown" fragments might have formed meteorites, which might have later encountered the earth, been attracted by its gravitation, and thus planted "moss" upon its surface.

One can only dimly imagine what the leaders of science would have said if such a theory had been put forward by some distinguished clergyman or architect or lawyer. The time has long passed when there is any need to discuss its details in a serious fashion; but it is of too great interest as a feat of the imagination and as part of the history of science to be wholly omitted here. The only comment which requires to be made upon it is that, even assuming all the incredible things which the theory requires, it merely alters the site of the problem, and we must ask just the same questions as before, except that we ask them of "another world," and not of our own.

Certainly the problem is not to be solved by running away from it, or pushing it away from us, in this fashion. Neither the miraculous intervention of Providence—as if everything were not miraculous!—nor the theory which pretended to solve the problem by saying it all happened somewhere else, can satisfy our minds to-day. What would satisfy them best can easily be defined, and then we can set to work to see whether this most simple and satisfactory explanation is really borne out by the facts of observation and experiment. The most reasonable solution would certainly be that, when we provided very satisfactory conditions of temperature and moisture and chemical mixture and air supply, we should find forms of life appearing there. These forms we should expect to be extremely simple and lowly, perhaps as much simpler than the amœba as the amœba is simpler than an insect or a fish; but if they were alive they would satisfy us, for if the amœba can give rise to an insect, these humblest of living beings might give rise to the amœba, and the chain would be complete.

This point, that the first and simplest living beings would be simpler than any we know, must be insisted upon, though it is frequently forgotten by students of this subject. But the evidence, up to the present day, entirely fails to demonstrate that living beings can arise in not-living materials. A vast quantity of work has been done, by Pasteur and Tyndall and Huxley, who are all gone, and by Dr. Charlton Bastian, who took the opposite view to theirs a generation ago, and maintains his view still.

The verdict then went to Pasteur's side; and we must try now to distinguish between the vastly important facts which Pasteur and his helpers proved, and the world-conclusion which it was sought to base upon them. Pasteur showed, by a long and magnificent series of experiments, that if tubes or vessels containing the forms of life which he called microbes, or yeast-cells, or any other of the humbler forms of life, be boiled or treated with a less degree of heat for a considerable time—a process now called pasteurisation—no life subsequently appears in them. They are sterilised, as we say. After the treatment which has destroyed all existing life, the test-tubes or vessels may be plugged with cotton-wool, which freely admits the air; but though all necessary materials, as we might suppose, are present for the formation of new living beings, and though the air has ready access to them, no life appears. These results, which have been confirmed incessantly since that time, were in utter opposition to the generally received belief. They completely upset the current views as to the origin of microbes and other agents which produce disease, and of course they are daily matters of life and death to mankind in their bearing upon the control of infection, the use of disinfectants and antiseptics, the preservation of milk and other food, and in many lesser ways.

SAND GRAINS, SHOWING THE STRUCTURE OF NOT-LIVING THINGS

But instead of keeping simply to the facts which Pasteur had proved, men drew from them the most tremendous conclusions, which are still generally accepted, but which these facts do not even begin to justify. Because no recognisable life appeared in certain boiled or long-heated solutions and mixtures, men actually assumed it proved that no forms of life, known

WHERE LIFE MAY HAVE BEEN BORN

Nothing is more probable than that life was born in the sea, perhaps in the primitive polar oceans which would presumably be the first to cool These photographs of the South Polar ocean were taken by the Shackleton Expedition At the top is a ship on the horizon, with numerous seals near the shore, below, an explorer is having a nearer view of the seals, the representatives of Life which were there before him

or unknown, ever appear in any part of the world, ocean depths, or hillside soil, in any circumstances except from preceding life; and many men went on to declare that the experiments proved that life not only did not arise from lifeless matter, but that it could not do so, either in the present or in any circumstances in the past.

It is the most difficult thing in the world to prove what is called a "universal negative," but here men thought to prove a universal negative as to the origin of life, on the strength of experiments which could not by any means include one in millions of the possible varieties of circumstances. There have been few instances of worse reasoning in the whole history of science.

Of course, men found their whole view of the world in difficulties when they argued in this fashion. Some looked for a Divine interference with the Divine handiwork in order to explain the origin of life; and others said the simple explanation was that life took origin somewhere else. But the final opinion, which is held as what we call scientific orthodoxy to-day, was that, while experiment proved that the origin of life where no life had been is impossible to-day, life must have arisen from not-living matter at some period in the remote past, "when the conditions were very different from those which obtain to-day."

The Earth Crammed with Life and all the Known Conditions for Making It

It cannot for a moment be admitted that the experiments have proved the origin of life now to be impossible, simply because, in those experiments, no life appeared to be produced. And it is hopelessly difficult to obtain any rational satisfaction from the generally accepted view that the conditions in the past were somehow so different that what is everywhere and in whatever conditions impossible now could have happened then.

On the contrary, if we try to compare present conditions with any that can have obtained in the past, we find that all the advantage, for the purposes of life, is with the present. The earth is now crammed with life; the conditions for the maintenance of life can never have been better: why not, then, the conditions for making it? All the required chemical elements are available, there is plenty of water, and of oxygen to breathe, and all the possible temperatures at which life can exist at all are available. Above all, there is a vast quantity of ready prepared food material, and of complicated chemical compounds, such as living bodies need and are made of, which have been made by the present life of the earth. Yet we are asked to believe that no life can ever arise anew on our planet now, in the presence of such things as starch and sugar, and white of egg, and milk, but that life could arise long ago when not a single one of the food materials which life relies on was available. This is the difficulty we find ourselves in, and there is only one way out.

The Marvellous Complexity of the Simplest Forms of Life we Know

We must give up the idea, for which we have no warrant, that the lowest forms of life we know are really the lowest and simplest that can be. This is a familiar type of error. The students of mankind, for instance, are only just beginning to realise that the lowest known forms of men are far above primitive man. Just so the students of life are now beginning to realise that the lowest known forms of life are far above what primitive forms must have been. Our error hitherto is almost ludicrous when we come to look at it. The amœba is the simplest form of animal life that we know, and we assume it to be the simplest that can be. Yet it has a complicated structure—much too complicated for us to have unravelled yet; and it possesses varied and delicate powers of locomotion, sensation, digestion, excretion, and reproduction, which have only to be thought of for anyone to realise that vastly simpler forms of life are imaginable.

Really it is amazing how we can ever have supposed that the amœba, or even the simplest of the green plants, is really primitive; and it is scarcely less amazing that notable students have been able to believe that such marvellously skilful and complicated beings could arise in a few hours out of a mixture of chemical compounds and air and water. It is as incredible as the view of the last generation that the civilisation and culture of Athens were built in a few decades out of barbarism, a view which we know to be as false as can be.

The Long Stages of Evolution of which We can Find no Trace

It is very probable that the simplest living thing we know represents the result of a long period of evolution, with many remarkable stages, all trace of which is now lost; and that the experimenters who deny the possibility of "spontaneous generation" on the evidence of a few days or weeks might as well expect the plays of Shakespeare to be written without the invention of an alphabet and a word or two

being necessary. If we are to possess ourselves of the only belief which satisfies the reason, and are to travel along the only road which will lead us to definite discovery, we must give up the idea of the amœba as primitive, and must ask what a really primitive living being would be.

All the living things we know now consist of cells, and cells are wonderfully complicated structures. It is reasonable to suppose that the simplest cell, simpler far than any we know, may have taken thousands or millions of years for its evolution. The modern study of the earth's crust gives us as much time for evolution to work in as anyone can ask for, or any theory require; and we who now have begun to realise what a marvellous thing the simplest cell is—how vastly more complicated in its simplicity than a man-of-war or a railway clearing-house—may well believe that many ages were required for its evolution. Long before the living cell appeared, thereafter to become the unit of all living things without exception, we may suppose that there was living matter, or protoplasm, as Huxley called it, "the physical basis of life." And now, what kind of living matter could it be that would first appear on the earth?

The Plant Life that Prepared the Way for Higher Forms

It would be in no sense an animal, nor yet like an animal in its habits. For animals, without exception, require for their food material which has been already prepared by the action of living things. Plainly, therefore, nothing of the nature of an animal could be the first living thing. This rules out the amœba, or even the simplest forerunner of the amœba.

If we turn to the plant world we find that microbes appear to be the simplest of its forms of life. But microbes are like animals, in that they can only live upon material which is itself alive, or which has been made by living things. Though they are plants they are degraded, unplantlike plants, and are as dependent on other forms of life as animals are. Thus we have ruled out both the simplest of known animals and the simplest of known plants.

The first forms of life must necessarily have been plantlike in this fundamental respect, that they could live upon materials not made by any pre-existing life. At some later stage the first animal forms must have been produced, able to live because their plant predecessors and contemporaries provided them with nourishment—as plants everywhere maintain animal life now.

Life depends upon chemical changes; and if all chemical change ceases, life ceases. "To live is to change," as Cardinal Newman said. And the words are literally true of every part and aspect of all life, bodily and mental. The only manner in which chemical change can occur for the purposes of life is in liquid water, which is the great solvent of other substances, and the great medium for their interaction.

When and Where Life May Have Begun in the World

All life is thus lived in water; and though we can say nothing whatever about the form of the first living things, we can confidently say that they existed in water. Indeed, nothing is more probable than that life was born in the sea—perhaps in one or both of the primitive polar oceans, which would presumably be the first to cool. A French physiologist has lately gone far to prove that the composition of the blood, even of man himself, is substantially the same, as regards the character and the proportions of its salts, as the composition of the sea-water of the primitive oceans, when, as we may suppose, life first left the sea.

These considerations help us, very roughly, towards some idea of the date of this tremendous occurrence. We may say positively that the origin of life must have occurred not earlier than the date when first the earth's crust cooled sufficiently to permit of the presence of liquid water upon its surface. And, so far as we can judge by the behaviour of life as we know it now, it would be likely that not until the first seas began to cool considerably, and their temperature fell a good deal below boiling-point, could life make a start.

Can this Marvellous Universe have Arisen from Dead Matter?

As for the date which these points indicate, of course we must refer to geology and physics. Geology has some kind of record, and may make guesses as to the age of the rocks in which remains of life first appear. Physics may reckon how long the earth has taken to cool. Other sciences contribute, as when chemistry studies the salt contained in rivers, and thence tries to measure the years during which the rivers must have been pouring salt into the sea in order to make it as salt as it is at present.

These estimates vary at present, and ever increase in length, as we gradually begin to learn the part which radium, and the powers of such substances as radium, have played in the formation of the earth's crust and seas. But it seems reasonable to believe

that life must have existed for not less, at any rate, than hundreds of millions of years.

So much for the probable place and the probable date of the origin of life. We have to ask again, in the light of our new knowledge, whether it can be believed that this marvellous thing, with its almost infinite powers and its conquest of the earth, can possibly have arisen of itself from what we call "dead matter." Here, as in so many other cases, the discovery of radium and its properties helps us beyond measure.

The Atom that Helps us to Bridge the Gap Between the Living and Not-Living

If we do indeed think of the not-living world as being composed of "dead matter," in the sense that its atoms have no force or appetites of their own, but are simply acted upon from outside, then it seems a simply unimaginable thing that such a marvel of spontaneous and original activity as life could have arisen in such unpromising material. We should find it easier to believe that life entered the world from somewhere else, or from nowhere, and possessed these atoms until they became alive. But the case is very different when, instead of our old ideas about "dead matter," and instead of looking upon atoms as forceless in themselves and merely the sport of forces outside them, we come to remember what very lively, if not living, things atoms really are.

Thus we come to the second of two ways in which modern thought and knowledge are learning to bridge the apparently impassable abyss between the living and the not-living. The task is indispensable for our theory of universal evolution, which cannot admit the presence of gaps in Nature, nor impossible intervals in the stride of things. We are learning to accomplish it by advance in both directions—from the living to the lifeless, and from the lifeless to the living.

The Mysterious Force that Works in Atoms Stored with Marvellous Energy

The gap between the amœba and "dead matter" is hopeless, but it is not real. The domain of life stretches far across the gap in living forms which, perhaps, have mostly disappeared from the world of to-day, but may yet exist, and may even now be in process of evolution from the supposed lifeless. We do well to remind ourselves of what the students of disease now say—that there are living causes of disease which are so much smaller than ordinary microbes that they cannot be seen by any microscope, if indeed they can be stopped by any filter. How absurd it is, then, to talk as if such things were the real beginnings of life!

And now the new chemistry throws out strong girders across the gap from the side of the not-living. It shows us that "dead atoms" are very far from inert in themselves, though they may be dead when compared with the forms of life we know. It shows us radium and other elements composed of atoms which are crammed with incalculable stores of energy, and are most certainly doing things at every moment of what we can scarcely help calling their lives. These new facts are none the less significant if we remember that certain atoms can act as ferments, causing chemical changes of an active and potent kind.

Constructive chemistry goes farther still. It builds up, from simple atoms, such compounds as alcohol, sugar, and even the simpler forms of the proteins, which are usually made by living beings alone, and which men supposed, not long ago, could be made only by the processes of living bodies.

We still talk, indeed, of "organic chemistry" and "inorganic chemistry," of which the first deals with the chemistry and the compounds produced by living organisms, and the second with other compounds. But every chemist knows that the two chemistries are one, and that the gap between organic and inorganic does not really exist.

The Strange Processes which may Hold the Key to all our Questionings

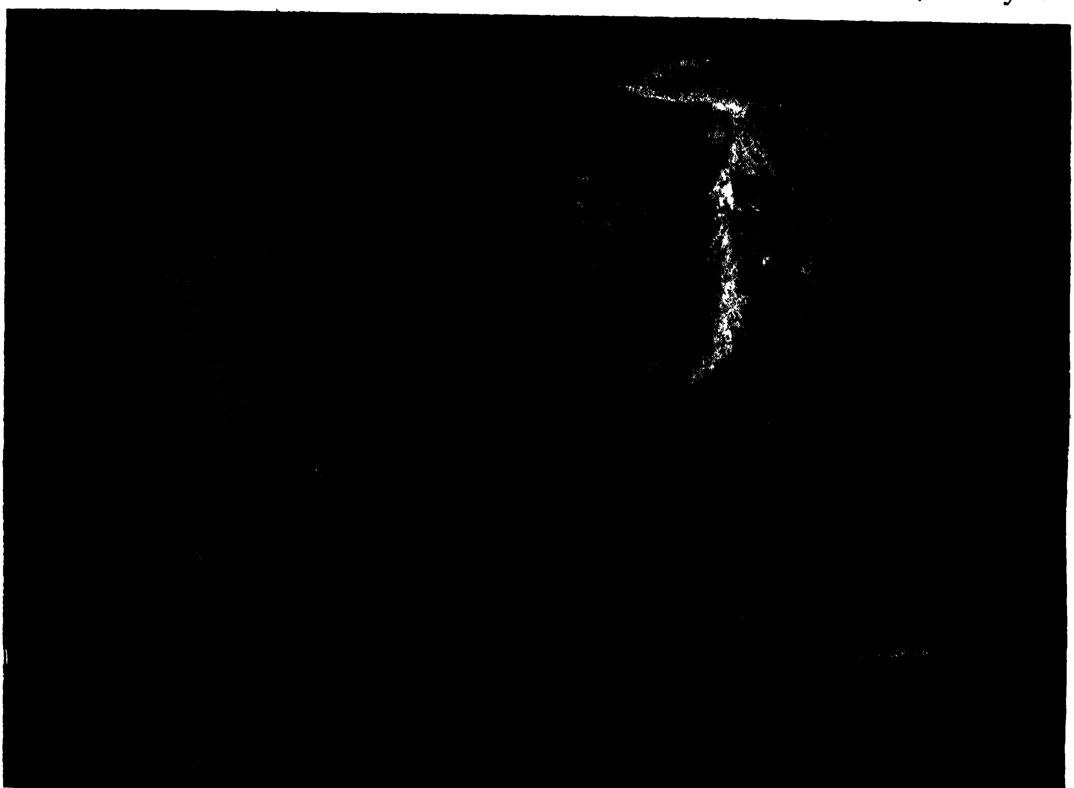
Not only does chemistry teach us never again to speak of "dead matter," not only does it construct so-called "vital products" artificially in the laboratory, but it directs our attention to a group of compounds, called ferments, which doubtless hold the key to all our questions. Clever experimenters suppose that they have produced living beings by the action of radium on bouillon; and others endeavour to galvanise special mixtures into the form or semblance of life. These attempts all prove disappointing. But the chemistry of the ferments makes steady progress. Some ferments can be made artificially—an achievement which perhaps is nearer than anything else, more talked about, towards the making of life. For ferments can produce and keep going chemical changes of the most wonderful kind, without themselves undergoing change or exhaustion. It is probably the literal truth that life, considered from the physical and chemical point of view, is a series of fermentations. All living things contain ferments, and cease to live if those ferments cease to be able to work. Great features of adult individuals are now realised to be due to the presence

or absence, or particular combination, of certain ferments in the germ-cells from which those individuals developed. The science of ferments has done more than all other branches of study put together to bridge the gap between the not-living and the living; and we must remember that the study is in its infancy.

A new branch of science has been formed to deal with this subject. It is called bio-chemistry; that is to say, life-chemistry. In its development are now hidden, and will ere long be revealed, the nature of fermentation, many of the mysteries of heredity and development, and most or all of the hitherto unsolved mysteries of disease, especially those concerned with abnormal forms of living action, such as the growth and behaviour of cancer-cells. Elsewhere we shall study some of this work, and note its progress.

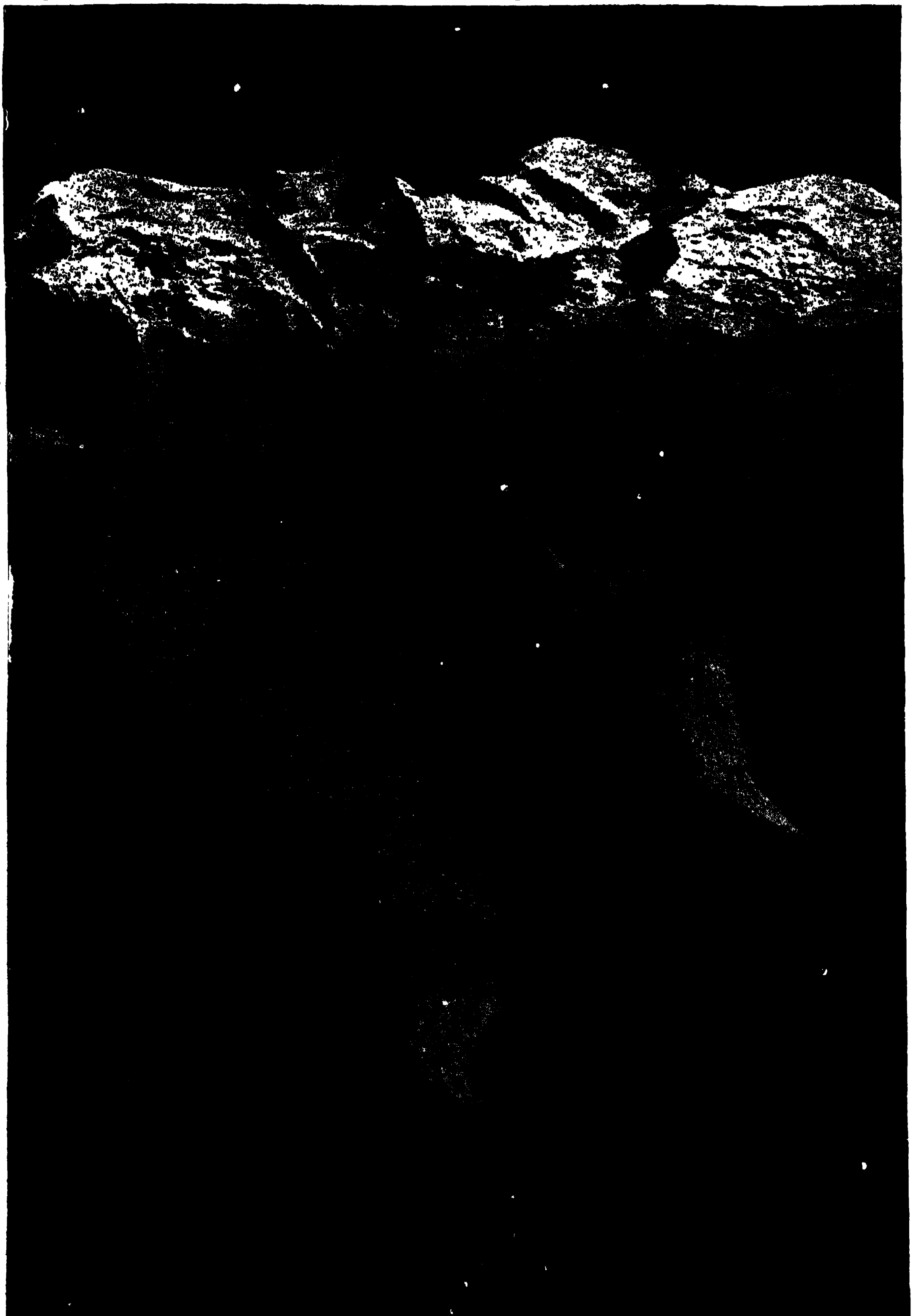
Meanwhile, we may be satisfied, by the first fruits of research already before us, that the gap between the not-living and the living is not without a bridge. All stages from the single unlinked atom, or even from the electron, up to the living organism, may yet be demonstrated, and even produced at will, by those who come after us, and the secret of the origin of life will be a secret no longer.

Life will be none the less real, however, none the less different and characteristic and wonderful, because we are able to trace its history and its connections, unless, indeed, we are always to discount or decry great things, great art, or great men, or great ideas, on the ground that we can trace "the base degrees by which they did ascend." If it be true, as modern science believes, that the possibilities of life are latent in the universe, that, as Tyndall declared, the eye of scientific faith can see in the fire-mist from which our earth was made all "the promise and potency of terrestrial life"—the worm and the bird and the oak, and Shakespeare and Plato—then the only conclusion we can draw is not that Shakespeare is therefore less Shakespeare, but that "dead matter" and "mere, gross, material things," and "the blind forces of the mechanical world" are less gross and blind than we suppose, since they are the servants and do the will of the living Power that moves through all things.



PROFESSOR TYNDALL, WHO DECLARED THAT THE EYE OF SCIENTIFIC FAITH COULD SEE IN THE FIRE-MIST ALL THE PROMISE OF LIFE AND EVOLUTION

HOW ROCKS ARE GROUND TO POWDER



A river of ice such as this played its part in making the soil of our islands. In the Ice Age huge glaciers must have crushed the rocks as a mill-wheel crushes grains of wheat, and in England many of the topmost peaks of hills have probably been pulled off and ground away by glaciers.

THE SOIL FROM AGE TO AGE

The Making of the Thin Coating of the Earth upon which all Life and Civilisation Depend

THE GRINDING OF THE EARTH TO POWDER

MANY people think of the soil, if they think at all, and very many write of the soil, as if it were made of the dust ground from the underlying rocks which great forces had broken and powdered. But it is also to be remembered that many little, almost unnoticed, and imperceptible forces, working steadily on and on for many thousand years, have done as much as the upheavals to break up the rocks.

Stones have been worn away by smaller powers than the dripping of water. In any wild, stony places where the air is fresh, lichens will be found colouring the hard stone with delicate greys and blues and yellows. It may be said that London and other very smoky towns are the only places on the face of the globe where lichens cannot live They need pure air and little else, and a stone is all they require to feed on. They distil on to it an acid, like the etcher on his plate, and thus make little patterns in whose grooves they may cling. Some of the stone they eat, some they break up and crumble. But what they eat and what they crumble is the beginning of soil.

All plants, from great trees down to small mosses and lichens, make soil in this way. A tree sends down its roots to rocks and stones far under the ground ; it secures from them, after it has broken them up, some of their minerals, which pass up the trunk and into the boughs and leaves. In all the leaves that fall is a certain amount of lime, one of the few substances that remain behind in the shrivelled leaf. This lime is each year added to the top soil. Much more stony substance is added when boughs fall and moulder, but on the whole it is the decayed leaves of trees, and both the leaves and roots of smaller plants, which add most to the soil.

This work results in such accumulation that we often find in a soil a large percentage of some mineral which exists in hardly perceptible quantities in the ground underneath. But year after year the deep roots of plants took what they could get of the minerals they required ; and when they died thus left life-stores as a legacy to the top-soil, so that in time this became richer than the under-rock. On the other hand we find certain top-soils that are almost devoid of the substances of which the under-rock consists.

Some plants, gorse, for instance, dislike lime, and yet will flourish over a chalk bed ; and it may be that this top-soil proves to be singularly deficient in chalk. Again, in the English fens of the Eastern Counties the most valuable lands are those which have clay underneath the black, peaty soil, for it is found that this clay is the most valuable of all manures for the soil. In other words, this clay, dug up and scattered over the surface, adds the minerals in which the black, peaty stuff is singularly deficient.

Quite often there is no connection whatever between the upper soil and under soil. If we walk over those wonderful flats which have formed in the neighbourhood of Rye during the last few hundred years we see the heavy beds of shingle that the sea left quickly become covered with soil. The soil in this case is almost all brought by the wind or by birds. In desert countries there are examples of soil being wind-borne over astonishing distances. Many soils are, of course, water-borne. The rivers have left fine deposits of the stuff which has been fetched from the higher regions. Again, the ice-caps, ages ago, scraped the high rocks and dragged down the worn stone to the valleys ; and great blocks of stone are carried downwards by the same force.

Even in England to-day, soil is found to be continually slipping down into the valleys with the help of water and moles and worms. Some valley roads, in spite of the stones added to them year by year, are now quite

below the fields on either side, as if they had purposely been cut in a hollow. Indeed, the top-soil is continually changing very rapidly under our eyes. The enormous part played by worms in England, and by the gopher in America, is incalculable. Darwin made many wonderful calculations in regard to worms which astonished the scientific world and created a good deal of incredulity, but he rather under-estimated than otherwise the accumulated effects of their work. It is tolerably certain that every bit of our more cultivated soil has been through the bodies of worms many times. They have both ground it smaller and have continually brought the finer stuff to the top. No one has yet calculated the effect of moles, but it is enormous—in some places much greater than that of worms.

We may truly say that the surface soil is manufactured, and it would be a marvel if it did not differ from the raw material underneath; yet it is not always accurate to speak of top-soil and sub-soil and soil foundation.

The Picture-History of the Making of the Soil that we see in a Quarry

It sometimes happens that we cannot tell where one begins and the other ends, especially in the valleys. At the same time, up almost any slope a section cut in the ground will show the divisions sufficiently clearly, and tell how one was formed of another. In any case it is useful to imagine and discuss a soil which was not brought from anywhere else, but came to be as it is by the slow process of the ages working on that spot and no other.

In many parts of England we can see on the sides of quarries a very simple and conclusive picture of the making of soil. No one who studied such a wall in the ground could have any doubt that the soil was made directly out of the rocks in some way or other. At the base is to be seen the solid, or nearly solid, rock. Probably even in the firmest blocks some slight cracks will be detected, and these give the first opportunity for the wedges of food and water to enter and begin their manufacturing of rock into soil. On the outside surface of the rock very likely some plants will be growing. As we have seen, lichens and mosses and such small hardy things as stonecrop can cleave to the rock, which is as much as to say that they have already made soil out of the rock. So the rock here is being made, or manufactured, into soil on two of its faces. However, now we are considering only the top side, where the manufacture is completed.

Above the solid rock is a mass of stones which look as if some roadman had been at work with his hammer. Some of the bits are small, some of great size, with every variety of rock in size and shape between these. This broken layer is often quite well defined from the under-rock. No doubt the under-rock is more freely cracked near the top, but the stones begin to multiply quickly, and very soon grow smaller and smaller, till they are almost powdered and become a sort of soil. Nevertheless, though they are in a sense soil, they are separated by a very obvious division from the top layer.

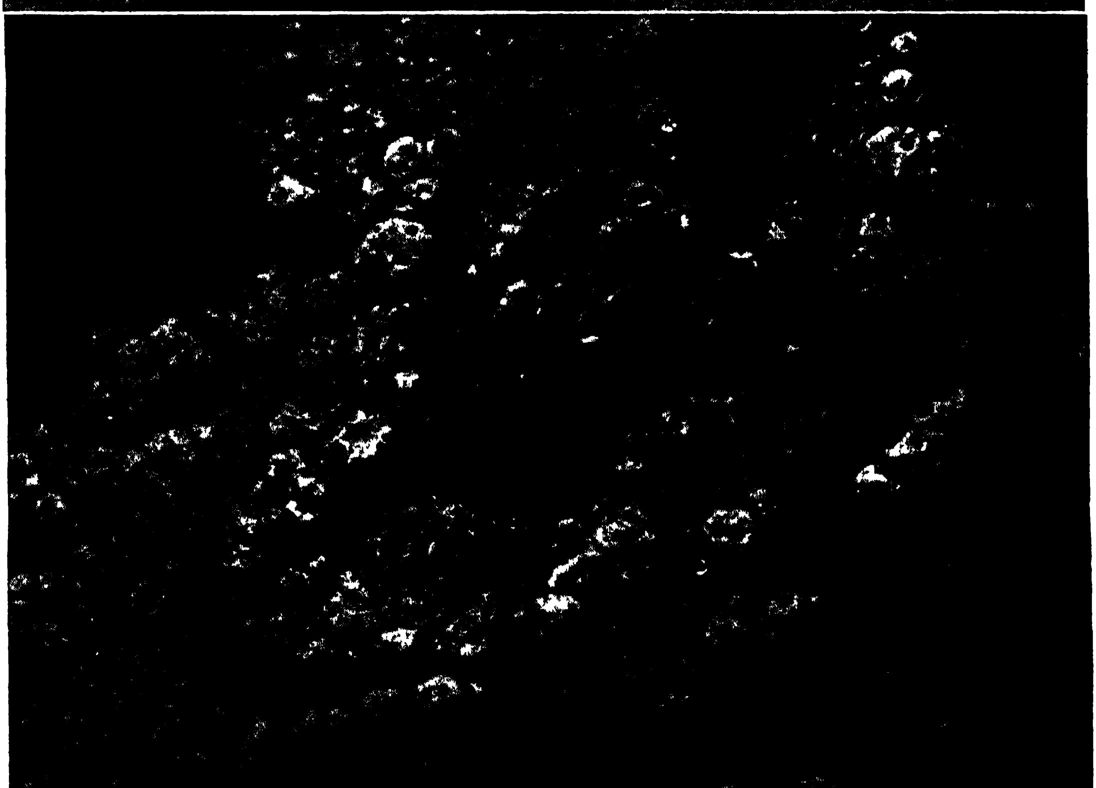
The Rock and Stones that lie Beneath the Surface of the Soil

They are separated, for one thing, in colour. Almost always the top-soil is darker than the under-soil or sub-soil, as well as looser and finer; and in this quality of darkness is something which makes the picture of this quarry-side harder to read and interpret. If one were asked to explain the picture one would find most of it easy enough. There is the rock of which any text-book of geology or the history of the earth could explain the nature. There anyone may discover the history of the rocks, how some were smoother, some pressed together, some deposited by animals and their shells. However, if all this may be left aside for the moment, and if we accept the rock as we see it as the primal foundation of the world, the appearances in the top-soil still remain unexplained, though all the rest is explained. The cracks show how the crumbling came about. Water trickled down. Ice froze in the interstices, and, exerting its enormous power, split the rock asunder. As soon as the rock was thus opened to the weather, the work of breaking up went on at double and treble speed.

The Thousand Little Crevices that Let in the Rain, which Breaks up the Rock

A thousand little crevices let in the acid that is found in rain, or the rain froze and the cracking was multiplied till a genuine sub-soil was created. But none of these things produced the dark colour of the soil above this. For that top "spit," or two "spits"—that is, spade-depths—is not wholly made of the rock. It is rather an amalgam of rock and air. Its colour is due to the roots and leaves of plants which have entered their substance both from powdered rock and from air. Many people get a wrong idea of the soil, and indeed of many things in and about the earth, because they regard a rock and the air as simple things, as elements. Of course, neither earth nor air

THE FIRST MAKERS OF THE SOIL



These were probably the first things to give life a resting-place when the earth was a bare rock. At the top is moss growing on a stone; below is lichen growing on bark. They are the simplest forms of vegetable life; lichen will grow on a stone, eating it and crumbling it away. That is the beginning of soil.

is an element. An element is a thing which cannot be divided into other things, without some addition. Iron, for instance, is an element. We cannot extract from iron any other substance than iron. If we add oxygen, iron becomes rust, but iron is iron, and nothing else. Now, both the earth and the air are many things. Almost any rock is a combination of all manner of things, such as silica, potash, soda, magnesia, lime, alumina, iron substances, water. The air, again, is made up of a host of substances, some only separated during the last few years.

The Soil of England that has been Hammered and Beaten from One Place to Another

This top piece of soil, then, is made up of a host of substances, very many powdered out of the rock, some stolen from the air by plants and by bacteria, those unseen but busy "flora" existing in their millions. Some of them, it is thought, are directly responsible for the black colour which distinguishes top-soil if it contains "humus," or some proportion of undecayed vegetable stuff. So it is never the case, or at least it is very seldom the case, that the surface soil is of the same soil exactly as the under-soil, and it does not follow that the sub-soil is of the same nature as the underlying rock.

In the section of ground we have described, the sub-soil was directly formed from the rock. If we could go back to the beginning of things, we should probably find that the lichens and the weather together first made soil out of the bare rock, the plants all the while adding a little, and as time went on more and more, of materials from the air.

But we can scarcely go back to the beginning. Our world has been hammered and beaten and upheaved and submerged by such violent and long-lasting forces that no natural order of things has proceeded over any long space. Nearly all the best soil in England was manufactured some distance away from its present site.

Irish Stones that Travelled to Scotland and Stayed There

For England, as most men believe, has undergone an ice-period—at any rate, all over the north—and a semi-tropical period also. It has been lifted high out of the waters, and it has been sent under them. Perhaps volcanoes and earthquakes have played their part. In many places we can scarcely penetrate down to any rock at all. For example, all down and along the Thames valley is a soil which is known as "drift."

Drift, in the first instance, is almost certainly made by ice. Ice-caps, ice-rivers—as glaciers may be called—have scraped and ground the rocks to powder. They have also caught up great blocks of stone, and carried these over long, sometimes enormous distances. In that form of drift, very common in England, and known as boulder-clay, we find stones and rocks of such rare and unusual sort that we can trace their origin with considerable certainty.

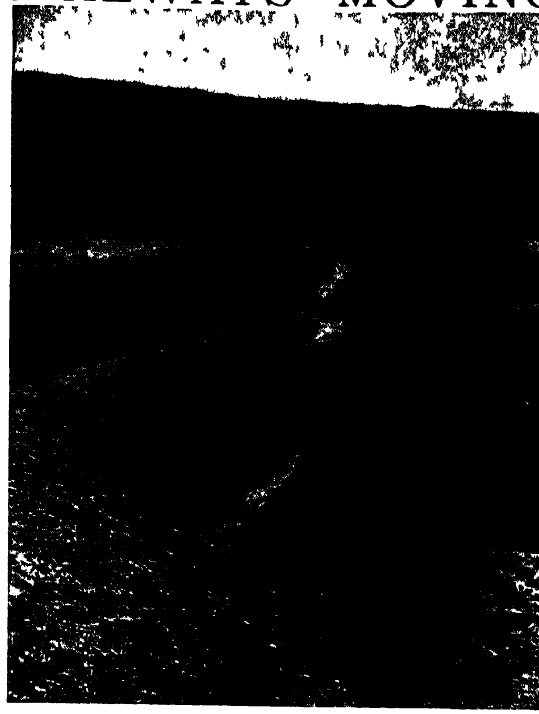
There exist in Scotland, for example, stones that must have been carried from Ireland, and on the east there are stones which it is generally believed came from Scandinavia, in days, perhaps, when no sea separated those distant places. One of the facts about these drift-beds which most astonishes people is their great depth. In the Thames valley they are moderately shallow, but on the East Coast they reach the extraordinary depth of 400 feet. Anyone who walks along the beach in the neighbourhood of Cromer, especially north of Cromer, can see this for himself. The face of the cliff is quite clearly made of layers of fine silt and dust, these layers being often twisted by various forces. As these layers have never, in most instances, been crushed or molten into rocks, they crumble away perpetually as the weather attacks them.

The Ice that Pulled off the Tall Peaks of our English Hills

We can see in them occasional lumps of chalk which must have come a very long way. Here and there brickworks have been started, showing where pockets or veins of clay exist. The more we look at these cliffs, the more clear and certain it seems to become that they were deposited there by some force which had ground them out of the rock, and carried them from the place of manufacture. They are, in short, what is called, in countries where ice-rivers still exist, "flour of glaciers." The glaciers have treated the rocks as the crushing wheels in a mill have treated the grains, and the flour or powder has been carried on along shoots. In moving the "flour," the glaciers and rivers have probably worked both together and successively.

It is a fascinating inquiry how this has all happened, but the important thing is the clear fact that it *has* happened in some such way as this. In England, glaciers have probably pulled off and ground away all the tall, sharp peaks of the hills, and the result has been the same as we see in any levelling operation. The hills have been lessened and the valleys filled up by the fallen rubble; and thus the shape of the surface of England has been formed, and the prevailing appearance is of a quiet undulation.

THE SOIL THAT IS ALWAYS MOVING


Most soil has come from elsewhere to the place at which we find it. Soil is continually slipping down into valleys, as in one of the upper pictures, and the picture of these trees, with their roots exposed, shows how a great depth of soil has been carried away by the wind and rain, which uprooted the trees.

If we had to give a general description of top-soil, it would be the soil as far down as cultivation goes—the soil, that is, which many roots and worms have penetrated and aerated, and ploughs and spades turned over. Of course, this is continually parting with its substance to the under-soil; and, except for the work of worms, which sets the matter right, the very fine soil has a tendency to sink and leave the top layers coarser than the under. But, generally speaking, the sub-soil is so different from the top-soil that if it is brought to the top it proves for a time very barren, because it has little decayed vegetation and few bacteria.

Why it is Good to Have a Chalk Bed in a Garden

The line between top-soil and the ground next beneath is most distinct in the places where the chalk comes nearest the surface. If we cut into the surface through the springy grass that covers the down, we find the roots and surrounding soil lying almost like a mat against the white beneath it.

Now, chalk is of especial interest and importance. More than any other underlying substance it has helped to give England some of its more beautiful country scenes; and certainly no other undersoil is nearly as useful for restoring to the top-soil its fertility. For hundreds of years it has been the habit of farmers to dig up the chalk and scatter it over the surface, and much loss has occurred because that habit has fallen somewhat out of favour in recent years. It is likely to become yet more popular now, for it is known that the bacteria on which the fertility of the soil greatly depends cannot work without chalk or some form of lime. The chalk, being alkaline, takes away from the ground the acid or sour nature which, above all else, prevents fertility. Some few plants, such as sorrel, thrive in an acid land, but they are the plants of least service to man and beast. Directly the land becomes acid the bacteria cease work, fallen vegetation does not fully decompose, and land falls out of cultivation.

The Millions and Millions of Shells that make the Cliffs of Dover

Nothing in geology, in the structure and building up of the ground, is more interesting than the chalk and limestone. On any piece of Portland limestone we can see, preserved in all the chiselled perfection of their graceful patterns, the form of the shells of which the stone is made up. Chalk is of the same nature as the limestone. It is no theory, as many geological beliefs are, but visible fact that the chalk was made of the shells of numberless animals, deposited year after year on the floor of the seas.

When we consider the enormous depth of some of the chalk downs—as the great ridge of the Sussex Downs, or the great Chiltern Down that begins to taper downwards at Dunstable—our minds are appalled by the thoughts of the ages which it must have taken to deposit year by year these masses of shells. It could not have taken, it has been calculated in respect of one ridge, less than two million years. Chalk seems to be of more importance in England than in other countries; and how many people first see it in the great chalk cliffs that guard Dover! Some people are inclined to think that chalk is not a healthy sub-soil to live on, but there is much reason to believe that it is as healthy for men as for animals and plants. But possibly different people are like different trees. The beech-tree flourishes best on chalk; while gorse, on the other hand, is among the lime-hating plants.

The Flints that should Never be Removed from the Garden

In chalky countries will always be found abundance of flints. In most chalk-pits you may see regular lines of flints, sometimes small and thin, sometimes thick and rugged. The half-clay, half-loam of the soil above the chalk will be full of flints. These flints were certainly formed in the first instance by gradual accumulation round some nucleus. We can, indeed, distinctly see the lines—as it were, the little strata in the flints—where the liquid mineral set and hardened. It is not unlikely that much of the soil above the chalk represents what is left from the chalk after it has been dissolved away. For chalk is one of the most easily destructible of the common constituents of the soil, and disappears very rapidly when in small particles. However, very often this overlying soil has quartz sand and other constituents which are entirely distinct from anything in the chalk; others must have come either from the strata that used long ago to overlie the chalk, or have crept down the hill from a distance.

The flints are of great importance in these soils. It has been found that if they are continually removed the land becomes poorer, and quite recently farmers have been refused permission to sell the flints off their farms. It is difficult to imagine any substance less fertile than a flint, but they are useful to the farmer,

because they hold the moisture and prevent evaporation. If we pick up any of the flints that continually come to the surface we find under them, in any frosty weather, plentiful crystals of hoar frost, indicating their relative influence; and owing to this fact the stony fields are found to require less manure. Farmers are apt to believe that these flints continually work themselves up from beneath. But the fact is that the fine soil is worked down, and the coarsest things remain above.

In colour and in composition the most direct contrast to the chalk downs are the peaty levels. Peat of a certain sort may be said to be made in any grass field. The close turf more or less keeps out the air, and a quantity of roots and rootlets do not completely decay. The result is that while any field is under grass it is accumulating food, if it is not pauperised by taking continual harvests of grass and given little or nothing back in manure. For peat is principally caused by the absence of chalk and the absence of ventilation.

Every cultivator should know the nature of his soil and sub-soil. Excluding peat, the rough divisions are only four—sand, clay, marl, and loam. These may be said to be in order of merit from the farmer's point of view, and the qualities of each may be briefly summed up. Sand has coarser grains than any other soil; and where the grains are coarsest we find either barren lands or lands bearing trees, especially pines and firs. On Surrey heaths, on uncultivated commons in the Midlands, we could almost infer the unkindly nature of the soil from an account of the underlying strata in any book on geology. Sand is made of sand rocks.

Clay, which is very common in England, is finer in grain than any other soil, and for that reason very close. In most cases the clay that the farmer has to deal with often comes from beds of underlying clay made perhaps millions of years ago by Nature's grinding mills. It may also overlie slaty, or crystalline, or even limestone rocks. Marl is a mixture of clay and chalk; and, since the one thing that will best make a clay soil workable is chalk, their superiority to the clays may be understood.

But the soil that every farmer most desires is a loam, and the natural loams are nearly all soils which have been brought or deposited. For loams are an amalgam. They contain, as a rule, all the other soils—sand that makes the land workable, clay and chalk that contain the proper mineral constituents. For the most part, they are the gift of rivers, and the rivers have left them neither too loose nor too solid, with no one substance in excess.

A DESERT AREA WHICH CONSTANTLY CHANGES THE FORM OF ITS SURFACE

THE MAN-LIKE MONSTER OF THE WOODS

THE GORILLA, THE TERRIBLE CREATURE THAT HAS NEVER BEEN CAUGHT ALIVE FULL GROWN

The gorilla makes its home in the twilight of dense forests. So terrible in its strength is this wild creature that men who have lassoed the rhinoceros and roped the lion shrink from a full-grown gorilla.

STRANGE THINGS LIKE MEN

The Curious, Intelligent, and Terrible Creatures which Parted Company from Man in the Twilight of the World

THE LIFE-STORY OF MAN'S POOR RELATIONS

MAN and his poor relations—the apes, monkeys, and lemurs—form the first order of mammals. Man has naturally a place of his own in this work, and here are to be treated the great families of the animal kingdom which share the earth with the lord of creation. While we shall not, in a popular work, follow the rigid classification of the scientists, we may glance, for a moment, at the arrangement of this first-class order upon which scientists have agreed. With man as the first family, the man-like apes form the second, arranged in three groups—the chimpanzee and the gorilla, the orang-utang, and the gibbon. In the third family are the Old World monkeys and baboons; in the fourth are the American monkeys; in the fifth the marmosets. That is the first sub-order of the Primates, and the lemurs form the second.

We shall glance here at some of the leading members of these various families of animals so near to man, representing something over two hundred known species. Many circumstances conspire to make the order the most interesting of all the divisions of the animal world. We no longer seek to hide the resemblance between the anthropoid apes and man; rather we take a fearful interest in tracing it. The man-like ape is simply a grim, repulsive cariacture of man. The higher ape is man's tragic might-have-been. Descended from a common stock, the apes and man diverged at some far-away point in the twilight which preceded the dawn of humanity. They travelled by paths progressively divergent; the differences become accentuated with time, and the contrasts become more emphatic.

The nearest of our poor relations is the chimpanzee, which inhabits a fairly wide range of tropical Africa. Its points of close resemblance to man are more numerous than those of any other of the apes.

Its canine teeth are less formidable; there is less disparity in size between the adult male and female; the bony protuberances over the eyes are less conspicuous; the whole structure of the animal, though true to the simian type, is less grotesque and forbidding than that of the gorilla or orang-utang. In height it is inferior to the gorilla, for, whereas the largest known chimpanzee is not over five feet high, a gorilla shot within recent years, near Tonsu, in the Cameroons, measured no less than six feet nine inches.

The body of the chimpanzee is thickly clad with hair of a dark hue, with lighter hairs here and there, and in some species is parted so evenly over the forehead as to suggest, at first sight, some attention on the part of the animal to its toilet. The ear is large and coarse, less like the human organ than the gorilla's, the nose is hopelessly depressed, and shorter than the gorilla's. The skin of the forehead is deeply wrinkled, and the animal has eyebrows and eyelashes. The chimpanzee, in common with the other apes, is tailless, but this animal has the arms shorter than the rest of the family. As the chimpanzee stands, its arms reach but little below the knee; and we remember that it was a boast of Rob Roy that he could fasten his garters below the knee without stooping.

The home of the chimpanzee is the low-lying equatorial forests, but in one district it is found far up the tree-clad mountain-side. Though some chimpanzees will eat a mixed diet in captivity, all of them when at large appear to subsist upon the wild fruits which flourish about their homes. They will, however, boldly visit cultivated areas, attracted by fruits of which they are fond. This is the only time, in ordinary conditions, in which they are brought in conflict with

human beings. They will make their escape, if possible, but if brought to bay they will seize a man and inflict a terrible bite. Livingstone states that when compelled to battle for the protection of their young against a leopard they will bite off the paws of the assailant; then retreat to a tree, moaning over their own wounds, and remain there until death releases them from pain. Though a slow-moving animal on the ground, where it can neither gallop nor run on all-fours, nor make progress upon its hind legs without support from its hands, the chimpanzee moves rapidly along the branches of trees.

The characteristics of the chimpanzee are best studied in captivity. Every zoological society of note has living specimens in its gardens. The London Zoological Gardens are fortunate in possessing six fine representatives, one of which has been in residence some thirteen years. On all hands it is agreed that the chimpanzee is a most intelligent and affectionate beast. With increasing years its temper may develop a certain sullenness, and its moods become a little dangerous, but to those familiar with its ways it is seldom very formidable. Many experiments have been made with a view of testing the intellectual capacity of this ape, and Professor Romanes succeeded in having the famous "Sally" taught to count up to five. If asked for any number of straws up to that total, she would place them, one at a time, in her mouth, and when the requisite number was reached would hand the whole to her keeper. Afterwards, the keeper continued the tuition with a view to extending her knowledge of numbers to ten; but though she was, as a rule, infallible up to five, and fairly dependable up to six, beyond that the results were mainly speculative.

Mansbridge, the head-keeper, who taught Sally, is still in charge of the apes at the Zoological Gardens, and has since made many interesting experiments with the chimpanzees in his keeping, and though he has not obtained further results of this character he finds the chimpanzee the most educable of all the apes.

The educability of the chimpanzee is proved by the surprising performances of many animals exhibited at places of amusement. Bicycle-riding and roller-skating are among their accomplishments. They readily accustom themselves to clothing, to eating with a spoon from a plate or a cup, and, after a few lessons, they behave with the gravest decorum at table. Brehm had a chimpanzee which responded with sounds expressive of pleasure to a voice that he knew. This animal was busy all day long in his room, using brush and duster, opening and shutting drawers and examining the contents, amusing himself by postures and grimaces before a mirror. Brehm, who urged the right of the chimpanzee to the first place in the scale of animal intelligence, asserted that *his* chimpanzee was actually a judge of human character, adding: "A thorough but accomplished hypocrite, who deceived me and others, was all along a horror to the chimpanzee, just as if he had seen through the red-headed rascal from the first."

Mansbridge has among his protégés a chimpanzee which, when suffering from two abscesses on the neck, would sit up without restraint to be surgically treated, and as his keeper approached, obviously with a view to the ape's treatment, would point with his finger to the wounds, as though to remind his master of his duty. Brehm's chimpanzee showed equal intelligence under similar conditions. Two surgeons, who were on good terms with the ape, did their best to overpower the poor brute, and to operate, but this was

ONE CHIMPANZEE FEEDING ANOTHER WITH A SPOON

impossible. Where force failed, however, persuasion succeeded.

"When the ape was quieted and reassured by the coaxing of his keeper, he allowed a further examination of the swelling, and even submitted, without twitching an eyelid or uttering a complaint, to the use of the knife, and other painful treatment. When this was done an unmistakable expression of relief passed over the sufferer's face, and he gratefully held out his hand to both physicians, and embraced his keeper, without having been asked to do either. When other complications caused the death of this ape, he died fully conscious, gently and peacefully, not as an animal, but as a man dies."

This docility under treatment is characteristic of the grown chimpanzee, but if its trial should come early in life it remains to the end of its days a timorous, affrighted creature, requiring the most careful handling.

THE FAMOUS CHIMPANZEE "SALLY"

Although three and a quarter centuries have elapsed since an Englishman first saw a gorilla, we still know surprisingly little of the habits of this man-like monster of the woods. The reason is that the gorilla makes its home in the dense forests of Equatorial Africa, in a perpetual twilight, and in an atmosphere like that of a conservatory devoted to exotic plants. The climatic conditions are almost intolerable to a European, and even if these be borne the surroundings are so dark and gloomy that careful observations of animal life can only be made with extreme difficulty. To secure a comprehensive study of the gorilla's natural history, we should have to render a second Herr Schilling proof against the physical consequences of residence in a malaria-haunted forest, and arm him with a flashlight camera. No adult specimen of the genus has ever been seen in captivity, and it is unlikely that any ever will, for such is the giant strength and ferocity of the animal when assailed that even men who have lassoed the unruly rhinoceros and roped lions in their lairs shrink from the task of making prisoner a full-grown gorilla.

The usual number of travellers' tales have gathered about the gorilla, such as his beating elephants with clubs, his capturing men and women, his seeking the natives' fire when its owners have quitted camp, but all these, with the stories of his unprovoked savagery towards all other forms of animal life, have been contradicted by the reliable data which, piece by piece, has been gathered to form the sum total of our knowledge of the beast. It had long been believed that the gorilla dwelt invariably in trees, or that the female with her young made her rude resting place in the tree while the male reclined, lightly sleeping, on guard at the foot, but we now know that the gorilla will, at times, roughly bind together a platform of vegetation on the ground, and there pass the night, with the female and young similarly accommodated close by. That these animals are proficient climbers is beyond dispute, and their physical equipment, despite the vast bulk of the male, is ideally adapted to arboreal existence. The huge hands and the prepensile feet, the enormous power of all four limbs, supported by a frame of incomparable strength, render the gorilla the king of forest life.

Happily, in the haunts to which he is restricted, there is little to challenge his supremacy. In his steaming forests little more than the occasional note of a bird gives suggestion of life other than his own, and the mightiest of the Primates lives, with his mate and offspring, solitary and terrible, a nightmare representation of the

handiwork of nature in horrific mood. This hideous monster of the forest twilight approaches in the shape of the brain and ears more nearly to man than any other of the apes. Like the chimpanzee, its wrist is fashioned on exactly the same plan with our own, a respect in which it differs from the other primates. It has a better developed calf than the other apes, and, though it has one pair of ribs more than man, it agrees generally with the rest of the simian family in its extraordinary structural resemblance to human beings. The vast and gloomy brows, and the immense tusks, or canine teeth, the hideous nose and protruding jaws, make it the vilest of vile caricatures of man.

The Fear of the Gorilla that will Drive it from Man's Presence

It is a convention to declare the gorilla invincibly savage and wantonly ferocious, but later gleams of light upon the subject show that it shares the nervous abhorrence of man common to the majority of wild animals, and that it will flee his presence as rapidly as the most timorous monkey. If unable to escape, then its rage is undoubtedly fearful; and at close quarters its mighty grip and terrible teeth make the animal a foe whose proximity the stoutest hunter might be glad to avoid. But the nature of the brute is not to be judged from conditions such as these. Even a rat at bay will fly at a man's throat, and a dainty little squirrel will bite in terror the hand which holds it. The young gorilla is as docile, tractable, and gentle in captivity as could be desired. Unfortunately, there has been little opportunity for observing the animal in public in London. Within the past quarter of a century the Zoological Gardens have caged six young gorillas within their boundaries, but the most painstaking efforts have failed to rear them, and not one of the six has survived long enough to recover from the effects of improper feeding and the long journey from the distant forest home.

A Young Gorilla on Board Ship which Knew it was Doing Wrong

All hope has been abandoned of rearing a gorilla in confinement, unless the creature has been kept captive near its birthplace, and slowly accustomed to hand-feeding and restraint, before being submitted to the ordeal of travel and strange food, leading to quarters in a climate as unlike that of an African forest as a summer's day is unlike mid-November.

However, though experiences with the gorilla have been unfortunate in London, we know sufficient of the disposition of the animal, in its tender years at all events, to realise that it possesses a type of mind similar to that of the chimpanzee, readily acquiring habits of sociability, good table manners, and the desire to romp and play with human beings. Something of the roguish guile of the child was displayed by a young specimen taken to Germany by Herr Falkenstein. This little creature was practically free of the ship by which it travelled, and was a general favourite. When it desired to have sugar or fruit, which it knew to be stored in a certain cupboard, the gorilla would suddenly quit its play and pretend to go in an opposite direction, only altering its course when it believed itself to be no longer under observation. Then it would dart to the cupboard, open the door, and with a dexterous snatch secure the article of which it was in search, sometimes closing the cupboard door before enjoying its plunder, or, if discovered, making its escape with its booty. The whole behaviour of the animal, at such a moment, made it clear that he was conscious of wrongdoing.

The Long Journeys of the Orang-Utang in the Trees of its Native Forests

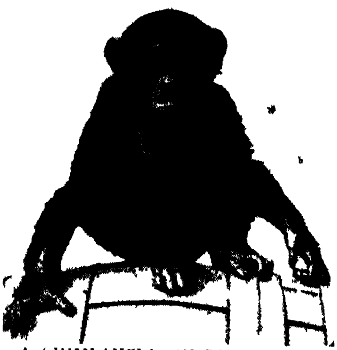
The "man of the woods," as the Malays call the orang, is a native of Borneo and Sumatra, of powerful but ungainly build, distinguished from the other apes by its brown skin, red hair, and small ears. The arms are of such length that when the animal stands erect they reach almost to the ground. The short, thick legs are so fashioned that the knees turn outwards, with the result that the animal walks on the sides of its feet, with the soles turned inwards. Thanks in the main to Dr. Alfred Russel Wallace, we are fairly familiar with the life of the orang in its native wilds. It is essentially a tree-dwelling animal, and travels considerable distances through the unbroken forests without descending to the ground. Though lacking the agility of the gibbon, it progresses at a surprising pace, hastening without hurry from treetop to tree-top, testing each branch before transferring its weight to a new position. This method of progression would be impossible but for an abnormally long arm, and the utility of these remarkable limbs is further evidenced by the animal's method of gathering its food from extended slender boughs upon which the entire weight of the body could not be borne.

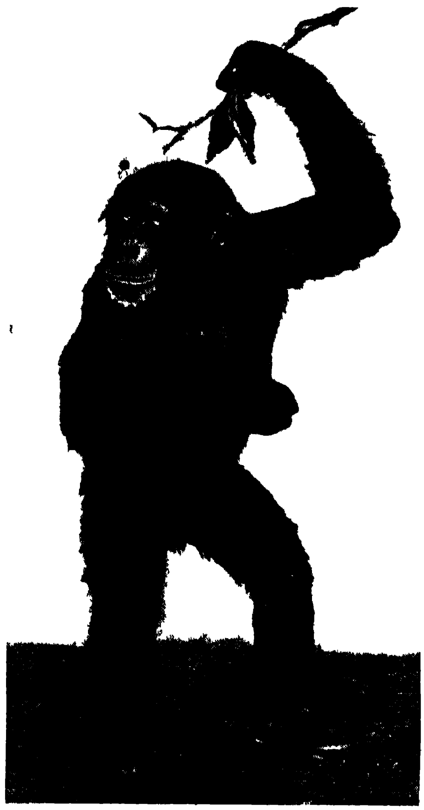
Structurally the orang is in some particulars farther removed from man than are


ORANG-UTANG AND CHIMPANZEE


CHIMPANZEES EATING TOGETHER


CHIMPANZEE FRIENDS


A CHIMPANZEE ON THE WATCH


THE CHIMPANZEE ERECT


ORANG-UTANG IN A TREE


THE CHIMPANZEE EXPECTANT


A BABY GORILLA


THE SILVERY GIBBON


THE HOOLOCK GIBBON

SOME TYPICAL MEMBERS OF THE FOUR FAMILIES OF MAN-LIKE APES

the chimpanzee and the gorilla, but in its "human" attributes it approaches as closely to the human as its relatives. The young orang displays a lively affection for human beings; and though it may be rather difficult to manage as it advances in years, it remains still a playful beast, a romping child in the guise of a monster. Dr. Wallace's story of his attempt to rear a young orang reveals traits in the animal which could not but recall to the philosopher's mind those of a human child. The animal cried and screamed when placed in its cradle; it showed unmistakable satisfaction when nursed and fed, but resented with vehement protest any attempt to impose upon it food it did not like. It was happy in its bath, happier still when having its coat dried and brushed. The young orang, like the young of the other man-like apes, is comparatively helpless; it owes its safe emergence from the perils of infancy to the care and affection of its mother.


AN ORANG-UTANG TAKES A WALK

The London Zoo has, at the time of writing, two very fine adult orangs, the larger of which has occupied its present quarters five or six years, after having spent a rather longer period in captivity at Singapore. Neither of these animals shows anything of the ferocity which at times characterises the adult orang when at liberty. It is fair, then, to assume that the orang, though conscious of its great physical powers and its ability to inflict injury with its huge teeth, is by nature peaceful and gentle, unless provoked to rage by interference or attack.

No reference to the orang would be complete without mention of the famous "Jenny" which the London Zoo once possessed. This animal, like those now in residence, showed distinct traces of humour and an absorbing love of play. By its gentleness and appealing ways it endeared itself to a distinguished circle of human admirers, among whom was Sir Richard Owen. A fascinating little picture occurs in Owen's biography, descriptive of a Christmas morning visit to "Jenny."

"She certainly attempts speech as far as her powers admit," Owen wrote. "When she is fond of a person, she puts her long, strong arms round his neck, and makes a curious noise, like an attempt to utter caressing words, opening the lips and moving them, as though trying to make certain sounds. She produces a sort of murmur, which one might easily translate into kind expressions. To-day she took a fancy, when out of her cage, to look out of the window, and slyly creep along till, under the pretence of friendship, she got there.

"The keeper pretended to be offended at her not coming when he called, and she ran up to him, put her arms about his neck, whispering to him and kissing him, till he seemed to forgive her."

The present keeper and his great lumbering pets at the Zoo can afford exhibitions just as interesting. To see "Sandy," the larger orang, forgive his master after a mock quarrel, shaking hands and kissing him, is sufficient evidence that the last of orang intelligence and gentleness of disposition did not die with the lamented "Jenny."

The gibbon, although it is the only ape which habitually walks in an upright position, is the least exalted of the higher apes. Its head is the most human in shape, but it bears the mark of the monkey in the form of naked patches upon the buttocks. The body is short and light, and the arms are so long that the ape, as it walks, can touch the ground with its knuckles. But it has progressed beyond need of assistance of that kind. It shuffles valiantly along with head erect, using its arms only as balancers, unless there should be some convenient overhead support, when it will grasp that

support, be it bough or bar, as an additional help. The largest of the gibbons, of which there are eight species, is only about three feet high, while the smaller species, in the adult stage, reach only two feet six inches.

When moving about on the ground, the gibbon always appears in a desperate hurry, as if afraid that its head might reach its destination in advance of its feet, and as it shuffles briskly along, with its arms waving ludicrously in the air, one might fancy it a child in furry "tights," balancing a heavy weight on its head. But, if awkward and uncertain when on foot, the gibbon is master of a form of poetry of motion when at home in the trees of its native forest. All the members of the family — which is restricted to the warmer parts of South-East Asia— are expert climbers, but the agile gibbon, in its swift, unerring flight from tree to tree, has no rival, save the birds. The lightness, grace, ease, and speed of its progress are indescribable. When on the move among the trees, these apes do not climb with the caution which characterises the movements of the other apes; they spring from bough to bough with amazing strength and speed. Hanging at full stretch by one hand, they leap to a distant branch, which they catch with the other hand. Without an instant's pause a second leap follows, when the hand first used is again brought into play, and then on uninterruptedly, each hand employed alternately, the leaps covering from ten to thirty feet, according to the distance of the bough at which the gibbon aims.

APES PLAYING IN A TREE

Any one of these longer aerial flights would be astonishing, but one marvel follows another until the eye of the observer can scarcely follow the flying animal. The absence of effort with which the jumps are made, the rapidity with which a bough is specially selected, so as not to check the swing of the flight, the ease with which the creature can twirl itself round a branch, sit at ease, and resume the journey without a second's delay, are achievements which leave the most accomplished human gymnast dumbfoundered. As we watch its passage through the air, we are not surprised that this animal should be able to catch a bird on the wing, a feat of which there is more than one record. The exploit suggests a purpose, and it is a fact that the gibbon, while mainly a vegetarian feeder, will eat young birds as well as insects.

Though gifted with a less highly organised brain than the rest of the apes, and disposed to overpowering nervousness which impels it to bite even those with whom it is ordinarily on most friendly terms, the gibbon is gentle and affectionate, and makes an engaging pet to those whose nerves are proof against the extraordinary volume of the cries with which it acclaims the morning and the night. In spite of the trying nature of the English climate, two of these animals at the London Zoo regularly enjoy the

liberty of outdoor cages during summer, and do very well in these conditions. There is a good understanding between them and their keeper, who has managed to regularise the gymnastic zeal of one of them so as to induce it to give astonishing exhibitions of disciplined agility.

Nature has been prodigal in plan and invention in dealing with the monkey groups. Nearly all the colours of the rainbow seem to have been given to some members of the family. We find them with flesh-coloured faces and hands, and nails as rosy and daintily shaped as any that engage attention in the boudoir. They are black faced, grey faced, brown faced; whiskered, smooth, and puckered; some with elastic cheek pouches, into which an assortment of food may be crammed for future use. They vary in size from that of a well-proportioned mastiff down to the modest dimensions of the squirrel. Some have tails of great length and stoutness, some have tails as short and mis-shapen as that of a thoroughbred bulldog; others have no tails at all.

THE LONG ARM OF THE SILVERY GIBBON

The photographs appearing in this group are by W. P. Dando, and others.

Noses play an even more important part among monkeys than is allotted to them in a famous chapter of "Tristram Shandy." Nasal organs of all sorts and sizes and shapes appear among them, from the little snub nose, hardly worth calling a nose at all, to the formidable organ of the proboscis monkey, which must at one time have had a reasonable chance of developing into a trunk. But there is one feature concerning the nose which the veriest tyro in zoology values. Here is a signpost pointing to the place of the monkey's origin. To the Old World monkeys and baboons the term catarhine is applied; the New World monkeys and the marmosets are grouped as platyrhine. The noses of the former have the nostrils close together and directed downwards; the nostrils of the New World monkeys and marmosets have the nostrils widely separated and directed outwards.

We have three clear points in respect of which the Old and the New World monkeys differ. There is this difference as to the formation of the nose; there is the fact that only American monkeys have prehensile tails, and there is the fact that, although not all Old World monkeys have cheek pouches, *none* of the American species possesses them.

The Old World monkeys and baboons constitute the third family of the primates, and are in eleven groups. First in our classification come the langurs, which, abounding in India, Ceylon, and Burma, are found also in part of China. There are fourteen species, all of slender build, with tails which may sometimes exceed the entire length of head and body. The best known of the genus is the hanuman monkey, the animal which every pious Hindu holds sacred. The consideration and friendship which he has experienced at the hands of the natives has made the hanuman the boldest of monkeys, and Hindu piety has been sorely tried, as troops of these animals have raided stores and shops whose owners dare not, for the sake of their faith, engage in reprisals.

This monkey, great thief as he is, makes some return for the toll that he levies, for friendship towards man seems now inherent in this species, with the result that in the wildest forests, remote from city life, the hanuman regards the appearance of human beings with favour, and, hovering overhead in the trees, is an infallible monitor when a tiger is in the vicinity.

When we reach the true baboons, we find Nature in her wildest, most garish mood. The baboons are the lowest of the Old World monkeys, and the Greeks and Romans discovered the canine character of the head and muzzle when they named them the "dog-headed" baboons. Their coarse, elongated heads, armed with teeth as formidable as many a carnivore's; the "all-fours" gait permanently adopted; the vivid colours of the naked buttocks and muzzle, conspire to make the baboon one of the most hideous of living animals. There are six species of baboons in all, each

one confined to the Old World, but excluded from the Oriental region.

They live in herds of varying numbers, experience having taught them the value of co-operation, whether robbery of cultivated plots be their object, or defence against a common foe. Although in the main dependent upon a vegetable diet, they will eat practically anything eatable, from lizards, birds and their eggs, to ants, scorpions, and centipedes. They are four-handed like the rest of the monkeys, but their extremities are better adapted to progress on the ground than to arboreal life. Some of them are very poor climbers, although this does not apply to their performances among the rocks, where they can travel with astonishing speed. In the open they never adopt the upright gait, except when sitting at rest or brought to bay. At bay they sit up, and an assailant realises that the fore-paws, which have so swiftly carried the animal in its flight, have suddenly reverted to the function of hands—excellent grasping implements by which a victim is drawn with great force to the baboon's terrible jaws. It is one of these animals, the mantled baboon, which we find sculptured on Egyptian monuments, and this animal was amongst those reverenced and accorded funeral honours. Nevertheless, the Egyptians combined utilitarian ends with their veneration, for sculptures show us that they taught the baboon to climb trees and hand down the fruits to slaves waiting below. The range of this particular species embraces the countries bordering on the Red Sea littoral and the Upper Nile valley, but the baboon tribe is widely distributed over the whole of Africa, the bold and pugnacious chacma in South Africa, the yellow baboon in West Africa, the mandrill in Western Equatorial Africa, forming conspicuous features of the fauna of the Dark Continent. The mandrill is, indeed, one of the show-pieces of the African continent.

TWO STUDIES OF THE ORANG-UTANG

A beast of immense power and ferocity, he equals in grotesqueness the wildest imagination of the artist in mythological creations. With its extraordinary coloration, this animal is quite without parallel among mammals. Its jaws are little less to be feared than those of the leopard, against which mandrills combine for defence. Its limbs, though comparatively short, are massive, with ample bone and magnificent muscle. Brutal and revolting as is the mandrill's appearance, the animal commands respect for a high type of intelligence. The same may be justly said of all the baboons, for, though they are the most repulsive of all the primates, they are entitled to consideration as having distinctly developed their brains. They dwell in the midst of powerful carnivorous enemies—lions, leopards, hyænas, and jackals—yet such is their courage and skill in concerted defence that they have survived the perils of the ages, to remain to-day a force with which cultivators of the soil have seriously to reckon.

The spider-monkeys are as much superior in point of activity to the rest of the monkey world as the agile gibbons are superior to the rest of the apes. But their pre-eminence arises from a different qualification. The gibbon's hand is a better

instrument than the hand of this monkey, in whom the hand serves for little more than a hook by which to swing from branch to branch. The tail is, however, a remarkable instrument, furnished with so keen a sense of touch that with it the monkey can convey food to its mouth, or employ it as an instrument for extracting food which the hand cannot reach. Most important, however, is the function of the tail in climbing. The spider-monkey uses his tail even more than his limbs in making his way about the trees in which he lives. The tail grips whatever it touches, so that observers have declared that it might almost possess the gift of sight. By its aid the monkey can hang head downwards, can drop considerable distances, and catch a lower branch without the employment of hands or feet; while in making prodigious leaps from tree to tree the animal relies fully as much on the grip of the tail as on feet and hands for its safe landing. It is perhaps fitting that this strange modification should occur in an American monkey, a native of a land in which so many remarkable inventions have had their rise.

The term spider-monkey describes, it is scarcely necessary to add, not the habits of the animal, but the character and action of the limbs, which are long and spider-like. It is not a little singular that the spider monkeys, though so wonderfully adapted to arboreal life, are more at ease upon the ground than many of their congeners, assuming an upright gait, and using the tail, curled into the form of the letter *s* as a balance.

THE YELLOW BABOON
which steals the crops of the natives of Western Africa

The howlers remain to be noticed. Six clearly defined species are known, each distinguished above all other primates, except the gibbon, for the power of its voice and the persistence with which the creature exercises it. Sunset and sunrise are alike proclaimed in deafening chorus, in which one voice of special resonance is said to lead. Less active than the spider monkeys, the howlers have prehensile tails, and use them to bridge gaps between one tree and another. They move over the tops of trees in orderly procession, an adult male generally leading a party of females, some of which carry their young on their shoulders. Arrived at a point at which the branches of neighbouring trees do not touch, the leader suspends himself by his tail, and, letting himself down, swings to and fro until he is able to grasp the neighbouring branch. The rest of the party follow suit, one by one, each at the point chosen by the patriarch of the family.

The true primates end with the marmosets, which resemble squirrels in form and habits; but, though the nails are so unlike those of the monkey as to be true pointed claws, instead of flattened nails, the face is that of a tiny monkey, and the teeth are thoroughly ape-like. The female gives birth, as a rule, to a litter of two or three, therein showing more affinity with the lower animals than with monkeys, which usually give birth to but a single young one at a time. The marmoset, though nervous and apt to bite when alarmed, is popular as a pet, not only in colder climes than its own, but in the vicinity of its native home, where native women are known to carry these little animals about with them, some secreting them in their bosoms, others hiding them in the luxuriant coils of their hair.

Relegated to the second sub-order of the primates, the lemurs and lemur-like animals are one of the most interesting sections of the animal world—not so much, perhaps, for their present-day claims to attention, as from their history and mystery. To-day, they form the connecting link between the monkeys and the insect-eating animals; but in that far-off epoch when new species were being fashioned, the lemurs, or a lemur-like ancestor, gave rise, it is believed, to all the primates. Superficially the resemblance between the lemurs and the monkeys is not immediately conspicuous. The lemur head is fox-like, and devoid of expression; the general form and gait suggest the true quadruped. But the points in which the anatomy of the lemur agrees with that of the monkey leave no doubt as to the lemur's being rightly included in the group of animals all four of whose limbs terminate in prehensile hands. Some fifty species of lemur-like mammals

EMOTIONS EXPRESSED BY ANIMALS

CONTEMPT

THOUGHT

SURPRISE

PERPLEXITY

SUBMISSION

MISERY

SATISFACTION

"The man-like ape is a grim, repulsive caricature of man, the higher ape is man's tragic might-have-been" Descended from a common stock, apes and man diverged at some far-away point in the twilight which preceded the dawn of humanity The differences became accentuated in time, but the apes and monkeys, as shown in this series of photographs, still bear astonishing resemblances to man

are in existence, but though a few strange examples of the order may be found in Africa, in Southern India and Ceylon, in the island of Celebes and the Philippines, the real home of the group is Madagascar.

The ghostly nocturnal movements of some of these silent-creeping animals, coupled with the glare of the large staring eyes, fill the natives of Madagascar with a superstitious awe; hence the well-being of the lemur, which is so abundant that every copse in Madagascar is said to contain at least one.

We find a striking variety of size, form, and habits among the lemurs, many characteristics quite unexpectedly appearing in the group.

From the adult indri, which measures two feet from nose to root of tail, we range down to the mouse lemur, which is almost as small as its name implies. We have lemurs whose agility challenges comparison with the monkeys; and lemurs, such as the slow lemur and the loris, whose movements are a model of deliberation; lemurs which walk by day, lemurs which creep by night; herbivorous lemurs, carnivorous lemurs; noisy, boisterous lemurs, and lemurs which never utter a sound except when angered or alarmed; lemurs which refuse to quit the trees unless compelled to cross a bare patch of ground to fresh quarters, and lemurs whose habitat is rocky enough to rejoice the heart of a baboon; lemurs with long, bushy tails, lemurs with short and stumpy tails, lemurs with no tails at all. In fact, Nature seems to have rung the changes upon lemuroid forms as completely as upon the pouched mammals of Australasia.

Some attempt has now been made to pass in brief review the chief groups into which the various primates fall. It remains to see to what extent these animals resemble man in points other than physical. The lemurs and marmosets may be left out of account, for, the lowest in physical and mental organisation, they are the least intelligent of the great group to which they belong. The psychology of the monkeys and apes is, however, quite a different matter.

A TYPICAL AMERICAN MONKEY, THE BROWN SAPAJOU

The ape brain is, after that of man, the highest yet, and it would be presumptuous to declare it incapable of further development. With all his mental limitations, the monkey shows strikingly human traits, and even his ill-temper in captivity and his inability or unwillingness to "learn," are explicable on other grounds than that of lack of intelligence.

There may be recalled an instance from the "Spectator," in which are detailed the exploits of a certain imp of mischief, named Jeremiah, to match the gloomy features which masked the fount of roguery behind. Jeremiah and his master had to move from one Indian military station to another, and the monkey, at the beginning of the journey, was given a seat in a new dogcart which his owner was taking, but he was speedily ejected as punishment for his destruction of one of the cushions. Thereafter Jeremiah was condemned to travel on foot, and arrived at the end of the day travel-worn, hungry, thirsty, and sad

Instead of eating the supper which was placed before it, the monkey sought out the biggest of a pack of outcast dogs which had assembled on the outskirts of the camp. It led the dog in, and gave it part of its meal. Next morning Jeremiah shared his breakfast with his new friend, and paved the way to its accompanying him on the day's march. Presently it jumped on to the dog's back, and rode triumphant. Each day the trick was repeated, the monkey feeding his canine charger, and completing the eighty miles' journey on its back. Jeremiah's unrehearsed, untaught manœuvres go far to justify the view that the monkey has a higher order of intelligence than the dog.

The monkey's perceptive faculties are exceptionally keen. It distinguishes instinctively between those whom it has cause to fear and those whom it has not. A distinct evidence of this was afforded in August, 1911, by a monkey which escaped from the establishment of a London dealer in wild animals, and betook itself to the housetops. It was in vain that the proprietor and his assistants sought, by every persuasive

RED-FACED SPIDER-MONKEYS

THE QUAINT TARSIERS, COUSINS OF THE APES

method known to them, to get near the fugitive. He knew the meaning of their blandishments, and refused to be charmed. But he went voluntarily, day after day, to backyards and street corners where children offered him food; he paid daily visits to an eating-house where patrons threw him morsels; he went down to casual sympathisers in the streets who had nuts and other delicacies with which to solace his solitude. But not an employee of the firm to which he belonged could get within arm's length of him; and ultimately the dealer, fearing to trust so powerful a creature to unfettered liberty, caused the poor beast to be shot.

The keeper of the apes at the London Zoo, who gets many things done by his charges at the word of command, is too wise to believe that apes or monkeys really understand human speech, but they undoubtedly appreciate the meaning of different tones of voice, he says. If an officer says "Attention" to a squad of soldiers, and next "Quick march," it is the difference in tone rather than the words used that conveys the meaning; and that is doubtless the way orders with which they are familiar act upon the mind of the apes. That seems feasible enough. An organ-grinder's monkey was climbing a wall covered with a creeper, to the serious detriment of the plant, when the present writer quietly protested. The grinder gave a tug at the monkey's chain and the animal leapt down; then, rushing away from its master, the creature bit the leg of the writer, who had spoken the words which had brought his climb to an end. It is reasonable to suppose that the monkey traced effect back to cause, such cause being the spoken words whose serious tone he had heard.

The monkey approaches human beings in curiosity. Other animals have the same inquisitiveness, as every hunter knows, but the monkey, as Darwin showed in an experiment with a snake and a paper bag which he placed in one of his cages at the Zoo, has the quality in irresistible measure. The monkey's love of fun resembles that of some mischievous larrikin, as when it snatches the property of some benevolent visitor, or knocks off the hat of the man who has fed it with the foods dearest to its palate.

It is hard to say where reasoning affection ends and blind instinct begins when the emotions of a monkey are concerned. Its natural affections are of the strongest, so strong that while it will endure immeasurable misery and suffering for its living offspring, that affection persists even after the life of the offspring is ended. Some monkeys will carry a dead young one for weeks.

A different type of affection is aroused, however, when a man is concerned. A good example is that classic of monkey fidelity which saved the life of one of the Zoo keepers. The keeper had to enter a cage in which were a powerful baboon and a small monkey, the monkey being in constant terror of the larger animal. The baboon made a sudden attack on the man, and fixed its terrible teeth in the back of his neck as he knelt on the floor of the cage. The keeper was a special favourite with the small monkey, and, seeing his peril, the little creature mastered its horror of the baboon. Leaping upon the baboon's shoulders, it succeeded in making the animal release the man, enabling him to escape, badly hurt, but alive.

THE IDEAL MEN OF OUR BRITISH RACE

THE MOST GLORIOUS SCULPTURE OF KING ARTHUR NOW EXTANT—AT INNSBRUCK

THE NOBLE STATUE OF ST GEORGE BY DONATELLO—IN THE ACADEMY AT FLORENCE

THE SEARCH FOR AN ANCESTOR

The Mystery of Man's Beginning, his Achievement of Supremacy, and his Far-off Allies in the Dim Mists of Time

THE FIRST KNOWN MAN IN THE WORLD

GRANTING that mankind is not a product of "special creation," but of growth and development, as we know every individual man to be, naturally we turn, with a quite new kind of interest, curious and sympathetic, to the lower animals, whom we now clearly recognise to be man's ancestors and allies.

We can no longer distinguish them as "the animals," as if man's body were not itself an animal. We must call them the lower animals, and we look at them not only for their own sake and their own interest, but with a personal interest also. Like ourselves, they are born to die; they are largely subject to our infirmities, and we to theirs; their blood can replace and supplement our own when we are in the grip of disease-microbes, which are alike our enemy and theirs; our relation to them is not merely a matter of external parallelism: it is a blood relationship in the profoundest sense of the words. The modern study of our minds, also, and especially of the roots and springs of our conduct, has combined with the more intelligent study of animal conduct and feeling to show that we are related to the lower animals in mind as well.

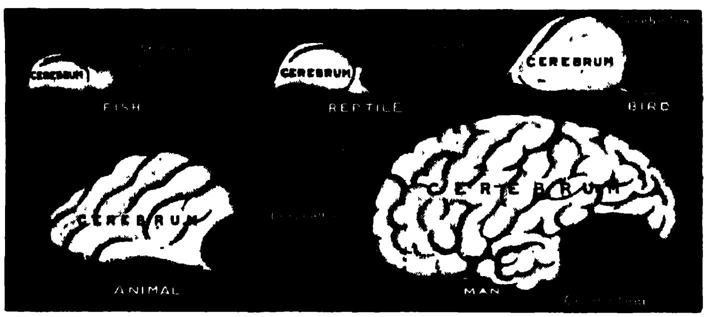
Hence the study of the animal world as a whole has incalculably gained in dignity, in importance, and in human interest through the Darwinian revelation of half a century ago. And thus, also, the study of man must begin with as close an inquiry as possible into his relation to his nearest animal relatives now existing. Let it be insisted not only that all life is one, but especially that all animal life is one. Hence, while it remains truer than Pope could realise that "the proper study of mankind is man," no modern writer on man does his duty who does not insist that the study of man is necessarily imperfect, and therefore less than proper, if it omits also to study life as a whole, and especially the lives, history, character, and conduct of the forerunners of man upon the earth.

Man did not spring from Earth full panoplied, like Athene from the head of Jove, and he must consent to survey "the base degrees by which he did ascend," even though the subject should be distasteful; even though he may be inclined to share the furious indignation of Carlyle when anthropoid apes were first exhibited at the Zoological Gardens, or the disgust which many sensitive women, and men, too, feel in the new Ape House to-day, at the spectacle of these hideous parodies, as they appear, of mankind at its worst. Perhaps it is scarcely kind to remind such readers or visitors, when they shrink from the snakes in the Reptile House, that, as was lately proved by a long series of experiments in the gardens, "only man and monkeys (including apes) have an instinctive fear of snakes. Rats, rabbits, goats, ducks, pigeons, and so forth have neither a dread of snakes nor a prevision of the swift death that may come to them."

Here is one more proof, added to the countless number adduced by the anatomist, and by the modern student of disease, that we are far more closely related to monkeys and apes than to any other living creatures. We even fear the same dangers —dangers which no other creatures fear. And we have reason. There is a large and most important group of diseases to which only man and the anthropoid apes are subject. The lower monkeys are as immune to infection by these diseases as, say, fish or birds are, but man and the apes promptly succumb. This extraordinary fact consorts with another, lately demonstrated by physiologists, that the blood of man and that of any of the man-like apes are practically indistinguishable by tests which will immediately and certainly distinguish

the same blood from that of any other animal. The scientific interest of the fact is evident, and its medical and legal interest is scarcely less. For nowadays the expert, to whom there has been submitted a blood-stain from a suspected murderer's coat, or from a knife, may be able definitely to disprove the assertion that it is the blood of a dog or a pig, and can say that it is the blood of either a human being or an anthropoid ape.

It may also be added that this relationship is of medical as well as medico-legal interest. The pioneers in the modern control of disease are long past troubling to argue as to the relation between sin and disease, or between man and the lower animals. They know that much disease can be controlled by the kind of knowledge which can be obtained only by observation of apes. But apes are scarce, and the men who are fighting disease have not so much money at their disposal as the men who show performing apes for holiday-makers to wonder at. Thus the apes usually go to the music-halls or the menageries, and the arrival of a cheap ape in Europe has before now led to the keenest competition among men of science in Paris, and Vienna, and Berlin, who knew that this creature might give them the key to the relief of some terrible malady of man. Already within the present century Metchnikoff, at the Pasteur Institute, has made a great stride in the control of disease by his studies on the blood-relationship between man and the chimpanzee.



BRAIN OF MAN COMPARED WITH THAT OF LOWER ANIMALS

We have made some brief mention of these kinds of evidence, because they are of recent discovery, and were, of course, wholly unknown to the evolutionary pioneers of the nineteenth century. Their chief interest may be practical, but they are also part of the biological evidence of the ancestry of man, and therefore demand a place in that connection.

Let us now set ourselves to the destruction of a popular notion to which too many writers have lent currency, and which has led, and still leads, to all manner of false arguments and wild-goose chases, not to mention our undue disgust when we contemplate a cage full of orangs or chimpanzees. It is the notion that man is descended from these animals, that his "first parents" were just such creatures, and that not only should he therefore be ashamed of himself, but he should also be able to find the "missing link" between these creatures and himself. But this disgust, wherever it may exist, is really uncalled for; the search for the "missing link" is futile, and arguments based on its non-discovery are worthless, for the excellent reason that the species of existing apes are not man's ancestors, and are probably quite as far removed, in their way, from the common ancestor of them and of man, as man himself is. The apes are not our ancestors, but our very distant cousins.

Darwin's only reference to this subject in the "Origin of Species" consists in a simple short sentence saying of his inquiries that by them "Much light will be thrown on the origin of man and his history." He said no more, because he feared, as well he might, the effect of prejudice upon the acceptance of his own views. He said no less, because he thought silence would be dishonest. Twelve years later, in 1871, he published his "Descent of Man," and meanwhile Huxley and Haeckel had shown what the doctrine of evolution meant for our theory of man.

Many lesser students have since contributed to the literature of this fascinating and all-important subject, but neither the pioneers nor any writers who knew anything of the subject have ever asserted or suggested anything so palpably impossible as that man, so highly specialised, could be descended from any of these anthropoid apes, all of which are so highly specialised in their own way. That is the purest nonsense, with no authority anywhere to support it. The scientific assertion, long past challenge, and notably confirmed by new researches, is that man and the four species of existing anthropoid apes have a common ancestry, which is not shared by any of the lower monkeys, not even those popularly called apes, nor by any other living creature.

Our ancestors were not chimpanzees or orang-utangs, and were, indeed, very much nicer to look at, though less like ourselves. Further, though we continue to look for and expect to find any number of fossil remains which suggest and amplify our knowledge of man's ancestry, we shall never find any "link" between us and the anthropoid apes, our cousins; and the absence of such links is no sort of argument against the evolutionary theory of man's origin.

Now we are in a position to make a beginning. Naturally, the first step is to study, more minutely than in any other case—and also more urgently, for the animals are disappearing—every feature of body and habit and character, of diet and gesture and incipient speech, and domestic and all-but-social life, which these four kinds of animals display. They must be studied in their native homes in Asia and Africa—for none are to be found in the New World, a point of enormous importance —and also they are to be studied, in other aspects, as we see them in zoological gardens and menageries. Some may be content to study them only in the music-halls, for which promising young chimpanzees are trained to smoke and drink; and thus, having proved themselves practically human—as humanity is exemplified and understood in such places—can earn three hundred pounds a week, until the tubercle bacilli in the atmospheres where they are exhibited make an end of them. Such intensely displeasing shows do certainly demonstrate the intelligence of these animals and provide for the psychologist most important data as to the degree and limits of their educability; but on all other grounds they are to be condemned, not least on the ground of the increasing rarity of these animals, and the priceless and unique services which they are able to perform for the study and relief of human distress.

Of the gorilla not much that is new has been learnt since its discovery nearly sixty years ago by Paul du Chaillu, whose account was so long regarded as a traveller's tale. The animal is exceedingly scarce outside its home in a small portion of Africa; and at the present moment, so far as inquiry shows, there are none in Europe, or, at any rate, none whom it would be polite to address as such. This, however, is the least important of the anthropoids from our present point of view, though it is, of course, very nearly the most interesting of all animals, and is treated as it deserves to be elsewhere in these pages. It has diverged much farther than the other anthropoids from their common stock and ours, and it is found only in Africa, which was not the birthplace of man. It does, however, approach man in the entirely unimportant point of stature, and, indeed, its tallness is one of the characters in which it is conspicuously unlike the other anthropoids, and far removed from the ancestral type. People suppose that the gorilla is nearer to man because it is tall, but its tallness really removes it farther from man, because farther from the ancestor by whom it and man are connected.

DISCOVERER OF THE GORILLA
M. Paul du Chaillu
Photograph by Elliott and Fry

Obviously, we must be guided in our search for this common ancestor by getting as near as we can from both directions. We must study the most primitive and unspecialised types of man, and the most primitive and unspecialised types of apes. Our difficulties are serious, but they must be met, or posterity will never cease to blame us, for the chances of knowledge are passing. The primitive races of man, on the one side, and the anthropoid apes on the other, are rapidly becoming extinct. The time is not far distant when not a single living specimen of either is to be found, and the gap in living Nature will then be the huge and incredible abyss between modern man and the lower monkeys.

DISCOVERER OF THE JAVA MAN
M. Alexandre Eugène Dubois

Such study as has been accomplished points us to the past for evidence from

fossil sources. We want something much more primitive than any existing men, and something much less specialised than existing apes. Fossil remains of man are found in various parts of the world, and fossil remains of anthropoid apes are found even in certain parts of Europe, where none of their descendants now live.

Of the ancestry of the gorilla we know nothing, and, indeed, it is only the gibbon that provides us with much fossil evidence. This creature, pre-eminently the tree-ape, as its scientific name implies, does indeed concentrate upon its small self the interest of tracing backwards the anthropoid ancestry.

As for man's remains, the number of which is constantly receiving remarkable additions—not least in Europe, though Europe was not his birthplace—we can indeed point to the evidence of skulls which show a formation of the cranium and the jaws more nearly allied to that of the apes than we find in any existing race. But this evidence, though of enormous interest to the anthropologist in his study of the races of man, is all too recent to tell us anything of his forerunners. The remains in question, however different in detail from modern types they may appear, are quite definitely and certainly human.

The Famous Man of Java, the First Known Man on the Earth

The case is different, however, with one piece of evidence, entirely unique, which was brought to light only a few years ago, and which, after much controversy and critical study by every anatomist and anthropologist in the world, is now accepted at the value put upon it by the discoverer. Near the close of the nineteenth century, of which the new theory of man's origin was the most startling and, for thought, most important achievement, a Dutch surgeon, Dr. Dubois, found in Java, in an ancient river-gravel certainly hundreds of thousands of years old, the upper part of the skull, and also a portion of the thigh-bone, of a creature to which he gave the name, now celebrated, of *Pithecanthropus erectus*, the "erect ape-man." Not a trace has yet been found, in Java or elsewhere, of a second individual of this kind, but, of course, these remains suffice to prove that a species of this kind existed, and there is every reason to hope that scientific exploration in these parts may find much more than these unique remains.

This is the creature which has been described as the long "missing link"; and though we know how inaccurate that term is, and that the so-called "ape-man" was no link between modern men and modern apes, yet certainly, for descriptive purposes, the term is justified. The creature was erect, we believe; doubtless not as erect as we are, but the evidence suggests that its hands were clear of the ground when it walked. Some anatomists have questioned whether the thigh bone, which furnishes this evidence, really belongs to the skull, but most consider now that it does.

The Mystery that is Hundreds of Thousands of Years Old

The thought comes, as we study these interesting remains, that perhaps we should not call the ape-man "it," for students agree that Pithecanthropus was a man—a man of sorts. He was nearer modern man than modern apes, but when his skull is compared with one of ours the differences are found to be very great. Its capacity must have been very small, compared with any human skull ever found—except for diseased skulls, such as those of certain types of idiot. The human skull contains a brain having some five or six times the weight of that of any existing ape—in proportion to the respective body sizes. The skull of the ape-man is definitely intermediate in this respect. It is very narrow, and has enormous eyebrow ridges. Its differences from a modern skull chiefly consist of serious defects in just the parts corresponding to those areas of the brain in which modern man differs most from the apes, as Sir E. Ray Lankester has pointed out with great weight.

About this extraordinary creature we know no more at present, though much more will doubtless be found when the work can be done. Unfortunately, there is no money in it, but only knowledge, but in this case the evidence, already hundreds of thousands of years old, will wait for our coming to it, and the mystery of Pithecanthropus will most surely be solved.

The Brain of the Java Man which Bridges the Gap Between the Apes and Ourselves

We know nothing of the teeth of the ape-man, for we have no record of his jaws, but we know that the number and characters of the teeth of the apes agree in most astonishing fashion with our own, and we possess, in the upper part of his skull, by far the most instructive part of the ape-man that we could hope for. This is all a matter of brains. It is the quality of the brain that, above all, distinguishes man from the anthropoid apes, and the problem of man's history is the problem of his brain's history

THE MAN OF ICE-BOUND EUROPE

It is thought that such men as this, very modern in type, may have survived the Ice Age in Europe, a period of perhaps thousands of centuries, during which the entire continent was probably frozen over.

That, above all, is where the so-called ape-man and the apes have their importance in our inquiry. No other creatures but ourselves have anything like their quality of brain. On this point the fiercest controversy has raged, especially around the powerful arguments long ago adduced by Huxley. He declared that, so far as brain structure is concerned, the anthropoid apes are nearer to man than they are to the lower monkeys. In other words, the gap between the anthropoids and all lower forms of life is greater in this most important respect than the gap between them and man. What we can infer of the brain of the ape-man of Java justifies us in the view that his brain was intermediate, historically, between our own and that of the common ancestor of the present apes, the ape-man, and ourselves.

The ape-man can scarcely be discussed under the heading of animal life, for he was really a man. Similarly, though the apes are animals, certain of their characters have had to be discussed here, as in Darwin's great book on man, because man cannot be understood without them. As regards the brain, we have not only the "ape-man," but much more evidence of a different kind since Huxley's notable work was done.

The Main Features of a Man's Brain that are Found in the Apes

The great work of Sir Victor Horsley and others upon the human brain, as regards the functions of its various parts, the localisation of brain-disease—made possible by our knowing what symptoms to associate with particular brain areas—and, above all, as regards the mighty achievements of brain surgery in which the English surgeon has been the pioneer—all these have largely depended upon the study of the brain of anthropoid apes. This study has in late years been largely undertaken by Sir Victor Horsley and other workers in order to serve surgical and medical science; but while it does so, it also concerns us here, for it demonstrates in amazing and novel fashion the closeness of the relation between man's structure and that of the ape. All the main features of the human brain, even to the arrangement of its convolutions or folds, are found in the ape's brain. There is no choice but to give them the same names in both cases. And this correspondence of structure is even less remarkable than the correspondence in the functions of different areas, by which the observer of the ape, assuming the facts to correspond in the case of man, may become the beneficent surgeon of his own species.

Such are the main lines of evidence, gathered since the general anatomical resemblance of man and apes was known and detailed, which satisfy all students nowadays that the forerunners of man were essentially ape-like in character, and that we, the rulers of the earth to-day, share in the possession of a common ancestor with the apes that live wild in the forest and captive in the cage.

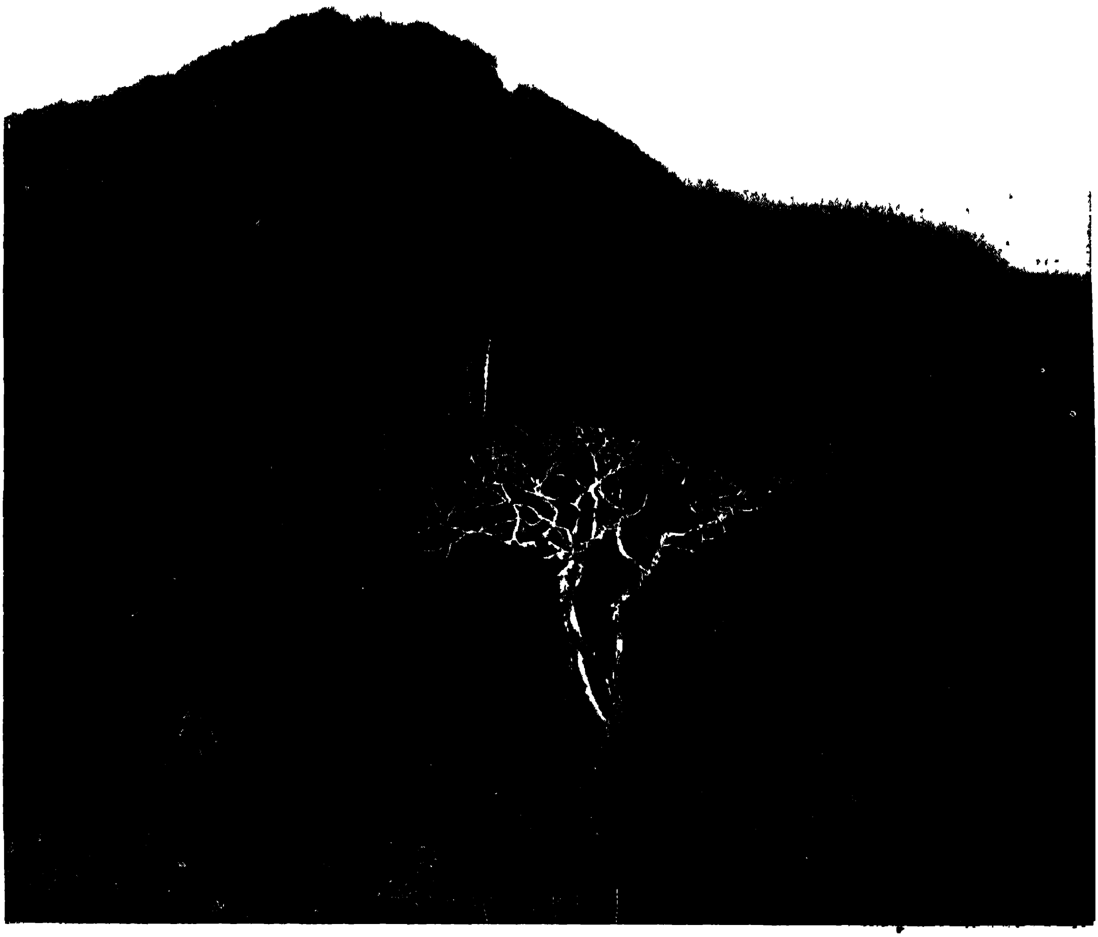
The Ancestor of Man Who Was Somewhat Like a Gibbon

These forerunners would not be like those apes, such as the chimpanzee, which most resemble man, but rather like the gibbon, which has diverged least from the earlier forms that we find represented in the fossil records, and which also represents the nearest affinities to other monkeys and the lemurs. The presence of gibbon-like forms in the past consorts with the other evidence in favour of the view that the forerunner of man, and of the existing apes, was a gibbon-like creature. Man's notable fear of snakes, and the anxiety of the gibbons at the Zoological Gardens when first they find themselves on the ground, are thus intelligibly connected; and much more, of still greater interest, may be inferred when we study in detail not merely the anatomy of the gibbon, but its habits of life and its geographical distribution. Latterly, much has been added to our knowledge of this creature, both as regards existing forms and those of the past. At the same time, there has been some simplification of knowledge—as when it was found that forms of gibbon with grey hair and whiskers, reputed to be a peculiar species, were only elderly individuals of species already known.

It is the study of the gibbon especially which combines with the other lines of evidence, and by which we may reasonably be permitted to reconstruct the first men for modern eyes. We shall find that our first parents have been much maligned, and cannot have answered at all to the popular pictures, which have persistently suggested an ancestor like the gorilla.

The First Man Must Have Been Without a Rival in the World of his Own Day

Our ancestors were not really like that at all; and they came not from Africa, but doubtless from some part of Asia, presumably not so far from those southern areas in which we find gibbons and other apes—but not the gorilla—to-day, and in which we have found traces of the least human of human beings, by no means the first man, but certainly the first man on

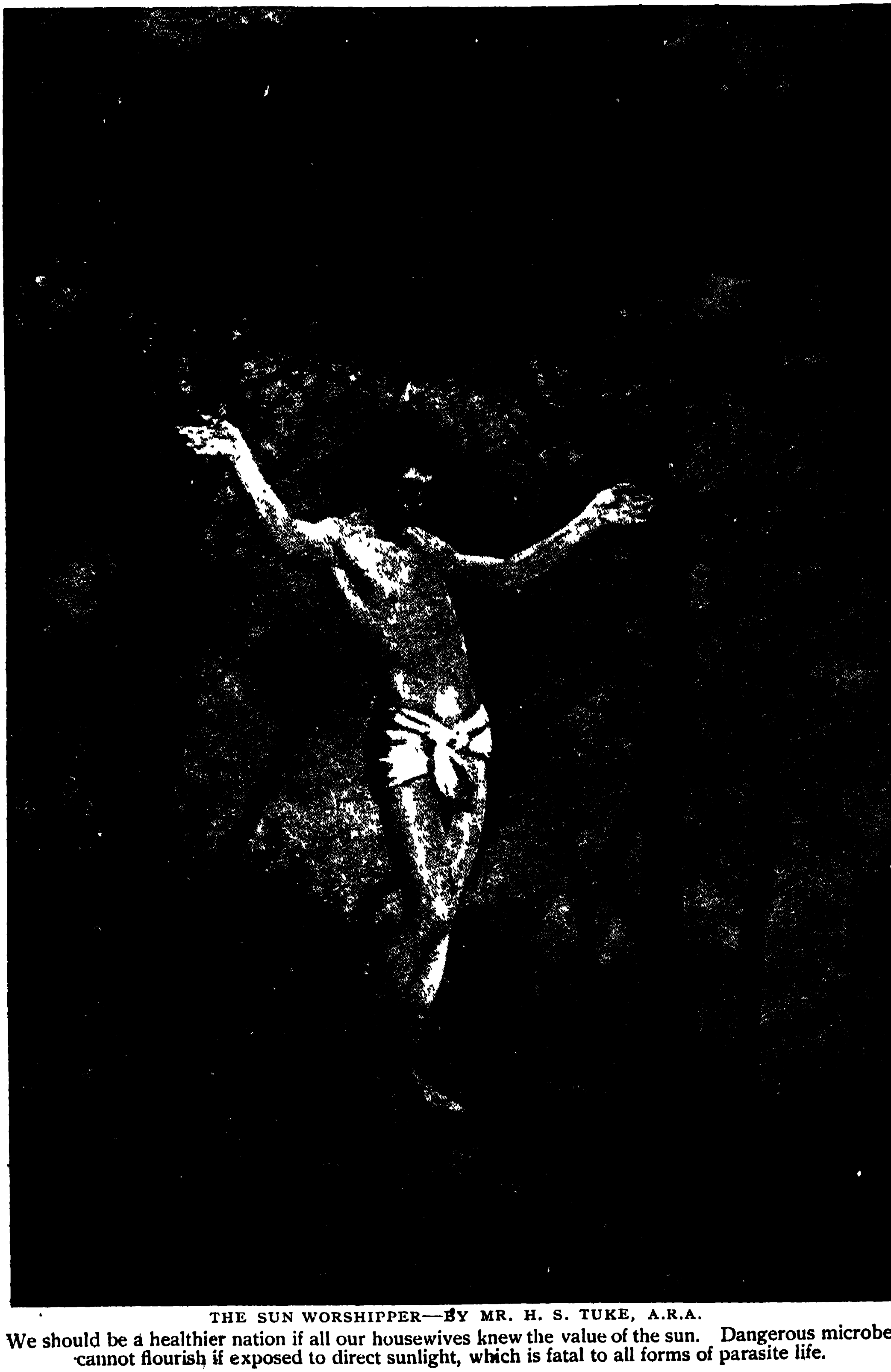


A FOREST SCENE IN THE ISLAND OF JAVA, WHERE REMAINS HAVE BEEN FOUND OF A MAN WHO LIVED THOUSANDS OF CENTURIES AGO

record. What, where, and how the first men were it remains for us to consider, but we shall consider to little purpose unless we keep in mind the leading facts about the forerunners of man. Our business is to satisfy ourselves as to what may be called man's "jumping-off" place, which, indeed, was a tree; and if we can agree as to the kind of creature which inhabited that tree, we may agree as to the kind of creature that found itself upon the ground, and has since explored earth and sea, and sun and stars.

No fact of limbs or muscles could explain such achievements, and we must not leave man's forerunner without looking for at least a moment at his mind.

The psychology of the ancestral ape is a subject of extraordinary interest, only to be appreciated by those who have studied the most recent work of Dr. McDougall, of Oxford. We shall learn in due course that the intelligence is not the whole of man's mind, or where would most of us be? Far more important for conduct are our instincts and emotions—not least those which maintain the life of the individual and that of the race. Here we are beginning to find a new interest in the ape, in his curiosity, imitativeness, suggestibility, educability, sociability, and amazing parental devotion. From our present point of view, the ape's curiosity, his educability, and his enterprise are of the most interest, as they suggest the forerunning of man's mind no less than the simian anatomy suggests the forerunning of his body. The ancestral being of whom man and the man-like apes are the descendants may have been mentally inferior to the least and lowliest of his present representatives, but he must have been utterly without a rival in the world of his own day. No wonder he wanted to see more of the world than he could survey from the fork of a tree.



THE SUN WORSHIPPER—BY MR. H. S. TUKE, A.R.A.

We should be a healthier nation if all our housewives knew the value of the sun. Dangerous microbes cannot flourish if exposed to direct sunlight, which is fatal to all forms of parasite life.

WISDOM & FOLLY ABOUT HEALTH

Every Man his own Doctor—Limited; and Every Doctor the Minister to a Mind Diseased

IS IT POSSIBLE FOR ALL TO BE HEALTHY?

HEALTH being our subject, we began in correct scientific fashion by an attempt to define and describe it. We have some idea now of what it really means to be a healthy man, and to spend twenty-four hours in a completely healthy manner. And now our business is to discover the laws and the practices whereby we may all attain this happy state.

But we must beware, or we shall fall into the error which has betrayed almost every writer on health until the present day. Notwithstanding the adage that "one man's meat is another man's poison," and the equally wise one that there can be no arguing about tastes, and notwithstanding the wise medical sayings which tell the student that he must learn to treat the patient, not the disease, since every patient differs from all others—writers on health persistently fall into the error of supposing that everything they lay down applies equally, or almost equally, to everybody. Time and experience always prove that this is not so, and doctors have long suffered in reputation because their general statements are so often found to break down when they are applied to particular people.

The time has come when this great mistake can no longer be excused. A new science, which studies the laws of heredity, and the natural "make up" of individuals, has proved how widely we all vary, so that every one of us is really unique in himself or herself, and therefore has unique needs. This science of Genetics, as it is called, must henceforth be remembered by the doctor who writes upon personal hygiene; and if he remembers what genetics teaches, he will perform his task better than it has ever been performed before. At every stage, whether he is discussing food or exercise or clothing or sleep, or anything else, he will try to remember, first, that in some most important things—such as having to breathe oxygen or die—we are all absolutely alike; and, second, that in many other things, very important to each of us, we are all entirely different.

Now, the wise doctor must rigorously lay down the law, if he knows it, for everybody, without exception, in the first kind of case; and he must try to describe the path of wisdom for all manner of different people—a different path for each—in the second kind of case. For instance, it is absolutely certain that we must all eat a kind of food called protein—found in such foods as meat and bread and milk and eggs—and the doctor must insist on this, and make sure that the people who follow his advice realise it, and do not try to live as if this law were not absolutely universal for every human being, as it is.

But whereas the text-books all assert the exact quantity of protein required for health by people of such and such occupations and such and such body-weight, the wise doctor, who knows how individuals differ, will avoid such unscientific assertions, which look so very scientific, and will try to indicate to his readers how they can find out what is the best quantity for themselves.

There is a familiar proverb, which few people understand, though it contains wisdom useful to everybody, which says that every man is a fool or a physician at forty. If this means that anyone at forty, unless he be a fool, can play the physician to other people, it is obvious nonsense. But it does not mean that. It does mean that every man who is not a fool should have learnt about himself, say, at the age of forty—better still at thirty—so much as to make him his own best physician in ordinary matters. He ought to know what suits

him, and what does not, what promotes his health and work, and what runs him down and upsets him—as no doctor on earth possibly could know. In that sense, which is enormously important, he is his own best and only physician, because he has devoted his whole life, so to say, to the observation and comprehension of a unique case, which is his own case. Plainly he must be the expert of experts—for himself.

The wise doctor who studies and endeavours to teach the laws of personal health must recognise these facts, and he must try, not to discover universal laws, which will prescribe so much sleep, so much fruit, so much reading, for everybody, because such laws would turn out to suit exactly one person and no more, but he must try to help people to help themselves, by stating those few great laws which apply to us all, since we are all human, and by then teaching us how to observe and take care of ourselves. And all the while he will beware of a very common and serious risk, which he must avoid—the risk of encouraging people to devote themselves to their own health, which inevitably succumbs, and over whose remains must run the words, "Killed by kindness."

Short Lives and Sad Ones, or Long Lives and Merry Ones

Indeed, that proverb about fools and physicians is rather severe, for it really amounts to writing down a great majority of mankind as fools. The impartial doctor, surveying his fellows, even those who are "old enough to know better," must agree that very few of them are satisfactory, judged by his standard. Many types of folly, of various degrees, can be witnessed.

There is the frankly careless man, improvident of health, though he may be prudent and tight-fisted as regards money. He does all manner of things which he knows, better than any doctor or any friend, are bad for him; and he continues to do them. The world is largely filled with this type of man, and woman too. Their average expectation of life is small, and their short lives are not even merry, as they know in their hearts, however brave and gay a show they may make for our eyes. The rule about lives, one need hardly say, is the opposite of the popular saying. On the whole, people have either a short life and a sad one, or a long life and a merry one.

At the other extreme is the man—and, of course, these remarks all apply equally to women—who devotes his life to prolonging it, and squanders his health in the effort to maintain it. These unhappy people read the medical papers, and they are constantly consulting doctors. They dose themselves incessantly with patent medicines, and with prescriptions which doctors have written for them, and other prescriptions which doctors have written for their similarly afflicted friends.

The Man who Destroys all the Joy of Health by Imagining he is Ill

They try all manner of diets and all the latest textures in underclothing; they frequently, in the course of their researches upon themselves, discover the normal and useful projections upon the back of the tongue, and suppose they have cancer; and their lives soon become a burden to themselves and to others. The present writer regards it as the most serious of his responsibilities to ensure that nothing shall enter these pages which will conduce to the making of such people, and to strive to teach and suggest laws of health, and ways of obeying those laws, which do not involve all this lamentable and disastrous devotion of people's lives to their own morbid fear of illness. If one must indeed choose between this and the other kind of folly, the folly of neglect is to be preferred. Both kinds of people shorten their lives, and do themselves harm, but the health fanatics and the hypochondriacs are miserable all the time, and the careless people at least get some intervals of happiness.

Another kind of folly may be called the conscientious kind; and no writer on hygiene can be better rewarded than by the thought that he may be serving its victims. These people ignore or try to deny the existence of warnings which should be heeded, because they feel it to be their duty to go on with their work at all costs. It is a noble and not an uncommon kind of folly. Nature makes no distinction.

The Price a Man must Pay for Burning the Candle at Both Ends

If a man "burns the candle at both ends" in order to get rich quickly and bully other people, or if he does so to make money for the care of an invalid wife or to bring success to some beautiful or unselfish enterprise, Nature makes her award just the same. We shall carefully study this matter when we come to the questions of work and overwork and worry. They are worth careful study, because the people whom they concern are the best and bravest and most valuable people in the community, and to teach wisdom to one of them is better worth doing than to help a multitude of selfish people.

Of notable importance, also, are those who misunderstand the adage about fools and physicians, and who, having found some kind of practice which suits themselves, seek to impose it upon everybody, in defiance of the facts of human variety. These cranks have their uses, and are often able to demonstrate important facts by the experiments which they make upon themselves. Very often, indeed, their particular theory or diet suits themselves admirably, and they are wise to adhere to it as long as it does so.

Their folly is displayed when they forget how men differ, and seek to make everyone well and strong by their own methods. Often they do great harm to their disciples, who are not suited to the particular habit or deprivation which suits the original crank so well. These remarks by no means imply that we shall merely laugh at—for instance—vegetarianism. On the contrary, we must study it most carefully, and we shall find that the vegetarians have taught us facts about diet which no one knew before.

The Food that may Strengthen a Man one Day and make him ill the next

Not only are all the candidates for health different in themselves, but each of them differs in need at different times. Health is to be attained and maintained in one way in childhood, in another in youth, and in another in old age. It is not only true that one man's meat is another man's poison, but that one and the same man may find one and the same thing meat at one time and poison at another. A man may profit by a meal one day, and be made ill for a week by a similar meal the next day, because he was eating it during a bout of intense depression or fatigue, which made its digestion impossible. Plainly, circumstances alter cases.

Another important fact, constantly forgotten by amateur students of health, is what we may call adaptation. Many of us, probably all of us, are now well enough adapted to certain kinds of work, or weather, or diet, or amusement, and would suffer if they were changed. But after a time we would thrive as well, perhaps even better, under the new conditions as under the old. If we examine one of the digestive juices of the pig we find that it contains one kind of digestive ferment in chief abundance when its diet is mainly made of protein. If now we alter the pig's diet, so as to make it consist mainly of starchy foods, its digestive juice alters in composition, and almost wholly consists of a ferment which deals with starch. That is simply adaptation; and all life everywhere, human, animal, or vegetable, involves adaptation, and would have little chance of survival without it.

When we are inclined to lay down the law about health in general, or our own in particular, we must remember adaptation, and be prepared to believe that there are wide limits within which we can live well enough; only that, as a rule, changes in habit, in food, clothing, exercise, sleep, and all the other questions which we are about to study, should be made gradually, so that the powers of our bodies may have time to adjust themselves accordingly.

The Doctors who Forget that we have Minds as well as Bodies

Another most important fact, which has been forgotten by medical writers on health until very recent times, is the influence of the mind on the body. Non-medical writers have repeatedly pointed out how important is the part played by the mind. They have declared that people's minds vary, just as their faces do, and that the state of the mind affects the body, so that what is good for one man's health may be bad for another's, simply because the two people look at it in a different light. For many years past, doctors have inclined to the view that their patients are to be looked upon as simply bodies, and have heaped terms of derision and contempt upon those who attached high importance to the difference in people's minds, and to the differing states of one and the same mind at different times. Modern research has altered all that; and it must be admitted that most of this fine work has been done, in the teeth of the doctors' opposition, by men whom they called cranks and visionaries.

The Grave Nonsense which Christian Scientists would exchange for Truth

The time for that kind of talk is passing. It is still the fact—an entirely mad and astounding fact—that a course of study in psychology, the science of the mind, is not included in the curriculum of a single medical school in this country, an omission to which the present writer has long called attention, and which must soon be remedied. For it is now clear to all men, doctors and patients and the general public, that the mind profoundly influences the body, as the body does the mind; and it will soon be realised that the attempt to deal with human beings, and especially ill human beings, as if they were merely animals, is unscientific, and leads continually to failure.

Health, as we understand it here, is health of mind and body, and health of the relations between them. The unpalatable lessons which "Christian Science" has taught the doctors in recent years will not here be ignored, and we shall endeavour to utilise them for our health, and to appreciate the work of those who have shown what mighty things the mind may do for the body. But at the same time we shall try to denounce and expose the appalling multitude of nonsensical and disastrous misstatements by which the Christian Scientists try to persuade us to exchange one half of the truth—that man has a body—for the other half of the truth—that man has a mind. Here we shall try to see both halves of all the truths we can.

The Mistake which Doctors and Educationalists have Constantly Made

One more point of the first importance must here be stated, lest we raise false hopes. The writers on health have constantly made the same mistake as the writers on education—they have supposed that all the human material which would come under their methods would be equally capable of profiting by them. The champions of the noble and invaluable science of education have almost always assumed and tried to persuade us that their process would make us all intelligent and well informed, cultured and devoted to learning. If their hopes have been disappointed, they have declared regretfully that their methods were imperfect, that certain changes must be made, the process must be begun earlier or not so early, must be prolonged later, must be more varied or less varied, the child must have no Latin or Greek, or must postpone starting these studies until it has had three years of French, and so forth. There is no end to all this, as every student of education knows. But, even so, we do not all turn out what we should like to be; and still less do other people turn out what we should like them to be. The truth is that education can only educate what is already there to be educated.

Two Essentials if we are to be Perfectly Healthy

In exactly the same way, and with exactly the same results, and for the same reasons, the students and champions of health, the cranks and the orthodox, the mind-healers and the drug-healers, the doctors and the herbalists, and the bone-setters and the Christian Scientists, all have promised health to those who followed their advice, and all have encountered many failures, and will continue to do so. Not only do we all differ within the limits of health, but we vary widely in our capacity for health at all, and in the degree to which we can profit by any observance of the laws of health, however faithful and vigorous. Education will not make the feeble-minded child into a normal adult; physical exercises will not make an adult man six feet high who was only five feet six (or even five feet eleven) when he started them. And in a thousand other respects—less obvious, but no less real—our possibilities are limited and determined by what we are to begin with.

That is why it was said, in our description of the healthy man's day, that the man who would attain it must be both fortunate and wise. He may be infinitely wise; he may be the best guide of other people, and may succeed in teaching health and achieving health for thousands; he may practise what he preaches, and all the while may be bedridden from some hereditary paralysis, or the victim of incurable asthma and bronchitis, because these maladies are "in the family." To be healthy, therefore, one requires not only to be wise in practice, but fortunate "in one's choice of parents."

The Fate of each one of us in Health or Ill-health is largely Sealed at Birth

In this fundamental matter, no writer on hygiene can very well guide the reader. Any prospect of "beginning at the beginning," which is the ideal of all true science and all sound practice, is out of the question. In very large degree, the fate of each of us is sealed before birth. The main lines of the building have been laid down, and we can do no more than do our best to keep it in good repair. But no care of a ten-horse-power motor-car will develop it into a twenty-horse-power, nor increase the number of its cylinders, though neglect will prevent it from developing the power which it was intended to develop, and may easily decrease the number of cylinders by throwing one or more of them out of action. This analogy between the machine of steel and the machine of flesh and blood is perfect so far as it goes.

We must here abandon, therefore, all the ignorant pretensions which have been too commonly put forward by writers on health in the past, and are still put forward by the vendors of special means for obtaining health. There is no certain recipe for health for all. If the reader's body or mind be like a ten-horse-power motor-car, we aim at the very useful object of enabling

him to develop his full power, and to retain it for as many years as possible. Not only do we regard it as futile to aim at making him the equivalent of a sixty-horse-power car, but we know that such efforts would do him serious harm. Any machine overtaxed, asked to do what is beyond its natural capacity, will soon cease to be capable even of that. Men with little hearts, perfectly satisfactory under proper conditions, seek to develop into champions of strength and endurance. They undergo special training, they climb mountains, run long distances; and after a short time the heart, instead of growing stronger, stretches and dilates, and they may be maimed for life. It is the case of the frog who sought to emulate the bull, and was rent in pieces by its own efforts at expansion. It might have made an admirable and perfect frog.

In this course of study, therefore, we definitely promise less to the reader than he will find promised or implied elsewhere. Follow he never so wisely the advice we tender, there are limits narrow in some directions, broader in others—which he will never be able to transcend.

The Rare Feat of Making the Most of a Man for the Longest Possible Time

No advice that we can offer here nor even any advice which future knowledge can offer, will alter the number of vertebræ in his backbone, or the colour of his eyes, or a thousand other facts of his constitution—visible and invisible, facts of structure and of function, of brawn and of brain—which are the beginning of him. He and we come in with our efforts when the beginning, and many stages later than the beginning, have been accomplished, for good and for evil.

Yet we also may promise more to the reader than these warnings may suggest—much more than he now expects, just because we promise so much less. Though nothing can alter his natural heritage, and though in some respects that is at least as important as anything which it is in his power to effect, yet, just because we recognise his limitations, he and we may in concert achieve the very rare feat indeed of making the most of him, and making the longest of him.

It is a feat so rare that, in strict judgment, we may, perhaps, say that it has never been accomplished. It is doubtful whether any man or woman, since time began, has ever achieved the utmost in the way of health and longevity which was possible for their native endowment. But, even if we ask for less than the utmost, we may be sure that not one in a thousand of mankind at the present time really enjoy the measure of health and longevity which is possible for them; and the contrasts between different people in their proportion of the possible that they achieve are enormous, quite apart from the fact that the measure of the possible varies in everybody.

The Candidates for Health and the Problems they Bring into the Consulting Room

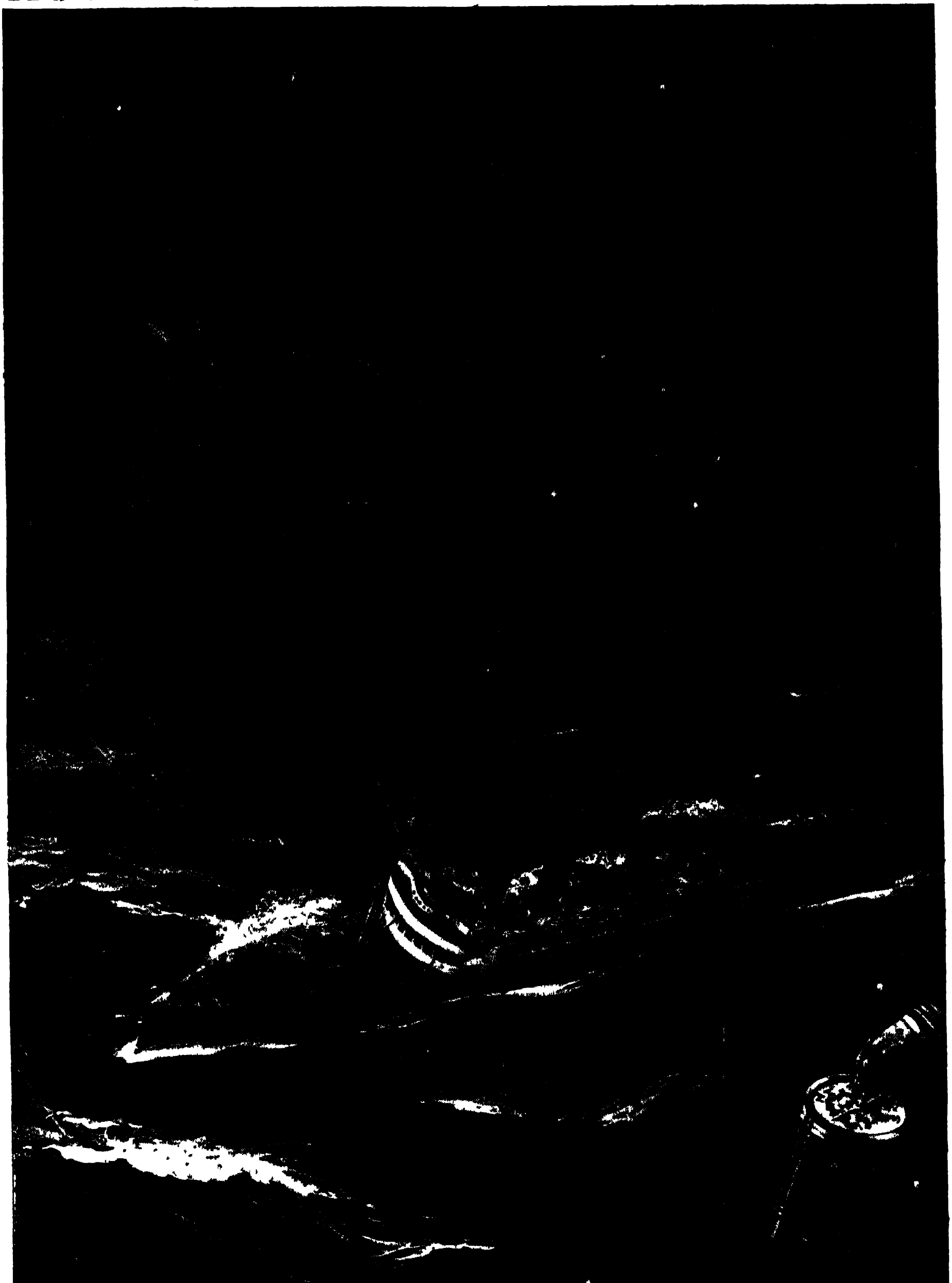
On all hands the doctor sees these contrasts, ranging from the man of magnificent natural health and physique, who ruins all in a year or two of folly, to the delicate youngster, already stricken with consumption, who makes a brave and wise fight—in matters of health bravery is no use without wisdom—and lives a long, useful, and happy life, crippled, perhaps, a hunchback perhaps, but a fine fellow nevertheless, in the finest sense of the word.

We have seen enough to realise what a variety of problems, soluble and insoluble, the candidates for health offer to the instructor, as they range themselves before him. Many of them he can do little with, short of having them born again and born different. Others have sufficient qualities of body and character to enable them to be almost independent of him, for they will soon learn, and put into practice, more wisdom about themselves than he can possibly attain. But he must do his best for all of them in the circumstances, and that may most surely be done by beginning, not at the beginning, for that is impossible, but at the few all-important points where health makes identical demands for all, and exacts similar penalties. The first of these is the question of the air we breathe and the manner of breathing it, and these we shall begin in our next chapter.

The Victory that is Higher than the Conquest of a City

Meanwhile, the facts of heredity and the importance of the natural heritage are not to be looked upon as wholly uncontrollable. On the contrary, to recognise one's limitations and peculiarities and special needs is half the battle of wisdom in matters of health and of conduct. Heredity and its laws are of profound interest, not only from the standpoint of Life and Eugenics—the groups in which they are discussed in this work—but also, as the wise reader will discover, they are of personal and selfish interest to us all, helping each of us to understand and thus to rule his own spirit, a feat which the wise king ranked higher than the conquest of a city.

HOW MUSIC CALLS A LOST SHIP HOME



THE DEFEAT OF FOG BY WIRELESS TELEGRAPHY—A REMARKABLE DEVELOPMENT AT SEA

The time when ships can be lost in fog is drawing to an end. By means of musical notes in wireless telegraphy, a ship may now find its latitude and longitude in darkness and fog as easily as at noonday. A port will have its own "note," and by moving a little instrument on the bridge, as shown in the corner picture, the captain may pick up this note and know exactly where he is.

MAGNIFYING OUR SENSES

How Man is Reaching out Beyond his Senses, and is Blotting out "Impossible" from the Dictionary

AMAZING JOURNEYS IN AN INVISIBLE WORLD

There have been two or three periods in the history of the human race when it seemed as if man were about to penetrate into the secrets of Nature. His intellectual power developed in a magnificent way, and his mind went voyaging on strange seas of thought in the illimitable spaces of the universe.

Always, however, man arrived at little more than a few interesting but unverifiable guesses. He was defeated by the limitation of his senses. His intellect was a marvellous instrument, which was prevented from working thoroughly and efficiently because its avenues of knowledge were amazingly imperfect. His eyesight, his senses of hearing, and of touch, taste, and smell, were greatly inferior to those of certain birds, insects, and animals; he lacked, too, the special instincts which enable many of the lower creatures to find their way across unknown tracks of country. With these imperfect senses he stumbled about the world, like an almost sightless beggar lost on a wild, unexplored moor at nightfall, and carrying a feeble lantern which threw a dim circle of light a few yards before him.

Lifting his eyes to the heavens, he could see only one or two thousand little points of light. Had he studied the sky in especially favourable circumstances, he might have been able to discern about two thousand stars. Yet the starlight that fell around him came from a hundred million blazing suns. When the day broke, and he looked down at his feet, he could only trace a few small forms of life; yet in the least piece of earth there were myriads of living shapes; and his own body contained millions of minute organisms. Colours that he could not see and sounds that he could not hear were all about him. The ground on which he trod vibrated under the impact of billows falling on a shore hundreds of miles away, and trembled with the waves set up by an earthquake which occurred, perhaps, a hundred years before at a distance of thousands of miles.

Every form of matter around him—the pebble he stumbled against, the stone of which he built his house, the metal he fashioned into tools—emitted subtle streams of electric energy. Yet, blind, deaf, and numbed to all this, man wandered about the earth, fancying that by mere guesswork he could come to understand and control the mysterious processes of Nature. But, before he could obtain any large and certain knowledge, he had to invent some thousands of exquisite mechanisms which would serve, in a way, as new and far-reaching senses.

Most of this marvellous extension of the senses of man has been won during the last fifty years; and the beginning of it only goes back to the age of Shakespeare. "What a piece of work is man!" said the great Elizabethan. "How noble in reason! how infinite in faculty! In action, how like an angel! In apprehension, how like a god! The beauty of the world! The paragon of animals!" Yet in what a narrow world Shakespeare lived—a little plot of earth, lighted with two revolving lamps, and covered with a blue roof, inlaid at night-time with bright spangles of light! The only things the Elizabethans found difficult to explain were the wandering stars—by which they meant the planets—and the comets.

When we contrast this quaint picture of the world with the universe of our days, and especially with our certain knowledge of this universe, we can get some idea of the enormous and sudden development of the senses of mankind in the last three hundred

years. What a multitude of great men—greater than Columbus—have recently extended the boundaries of human knowledge! Not only have they opened up a strange, illimitable world above our heads, but they have discovered a more wonderful tract in the ground on which we thoughtlessly tread. Overhead is the infinitely great; beneath us and around us is the infinitely little. And it has all become visible—visible to our senses—that is the almost supernatural marvel of it. Here, on the one hand, are Sir William Huggins and Sir Norman Lockyer asking us to look at their spectroscopes, and see with our own eyes the elements of which some star, millions on millions of miles away, is composed. Here, on the other hand, are Sir J. J. Thomson and Sir William Ramsay wanting to reveal to us the mystery of matter. They do not want us to believe anything: they, too, ask us to see. Look! These are the corpuscles of which an atom is built. The electric and magnetic currents are sending them in a stream against this screen. We can measure them - their velocity, and their mass, and the charge of electricity they carry. We cannot remember the figures? Well, here is a photograph of the thing we have seen. Let us make our calculations from it.

More Separate Lives in a Drop of Water than Human Lives on the Earth

After gazing at the wonderful scene—at the Royal Institution, very likely—we study at leisure the photographs taken during the experiments. If we have a head for figures, here is the conclusion at which we arrive: in a single drop of water there are far more separate entities than there are human entities upon the earth—there are about 2,000,000,000,000,000,000,000 molecules! These molecules are divisible into smaller parts, which are called atoms. A little while ago an atom was not a thing, but only a theory; it was merely argued that matter might consist of atoms before it was made up into different elements.

Well, let us suppose that an atom could be magnified into the size of a large room—an utterly impossible feat, for the atom is much smaller than the smallest wave of light, and no microscope therefore could define it. Still, let us suppose that an atom could be thus magnified: then the corpuscles of which they are composed would appear like specks of dust in the large room. Yet now the mass and velocity of these corpuscles can be measured!

A little over three hundred years ago, the vision of the keenest-sighted human being was inferior to that of an eagle. Now man has broken up the atom, and he has seen it breaking up. Turning from the study of the heavens, he picks up a fragment of earth beneath his feet, analyses it into parts more numerous than all the millions of stars in the sky, and then discovers that each of these parts is an arrangement of forces as wonderful as the arrangement of the solar system.

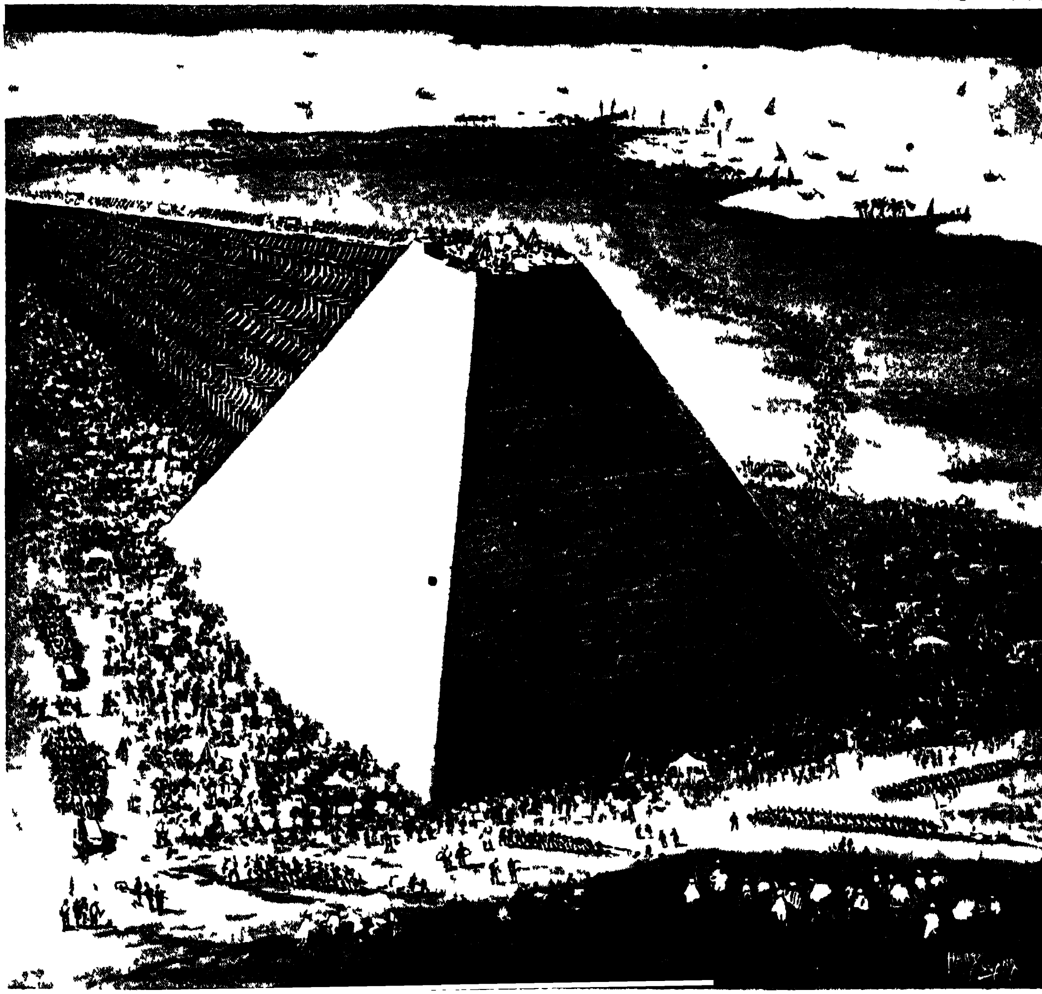
Man May Hear To-day the Tremors in the Earth which Napoleon Might have Heard

All this new science is founded on observation and experiment; that is to say, it is founded on the evidence of the senses. But these senses are newly acquired faculties. As by the stroke of a magician's wand, the almost sightless beggar lost at nightfall on an unexplored moor has swiftly been transformed into a giant. His actual voice resounds over an entire continent; with the speed of lightning he sends a message round the world; his vision penetrates into the fiery core of the remotest star of heaven; he can feel the heat of a candle burning over a mile away; he can discern the infinitesimal microbe; and he can weigh the earth on which he stands. Putting his ear to the ground, he listens to the beat of the surge on some far-off shore, and hears to-day the echoing rumble of some terrible earthquake that happened in the days of Napoleon; then perhaps he feels a new movement in the earth, and in a few minutes he has traced it to its source, maybe in some Asian desert. Such is the infinite delicacy of perception which is combined with the extraordinary power and range of the new senses of man.

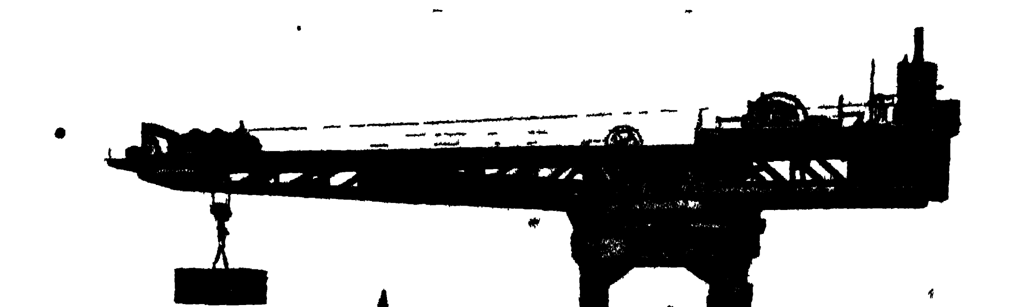
The Power within Man's Grasp for Thousands of Years

By a curious piece of irony, it was when man was losing some of the small natural power of his eyesight that he first attempted to extend his senses. In the ruins of the palace of Nimrud at Nineveh has been found the earliest-known form of magnifying-glass. We can see it at the British Museum. It is a convex lens of rock crystal, four inches long, and nearly one and a half inches across. For thousands of years man made no use of this wonderful invention, except to increase his power of vision when it was failing through old age or natural short-sightedness, or when he needed a finer definition in gem-cutting. Even when, in the thirteenth century, Roger Bacon worked out the principles of both the telescope and

MAN'S POWER IN TWO CIVILISATIONS



THE BUILDING OF THE GREAT PYRAMID BY MEN MASSED TOGETHER LIKE ANTS



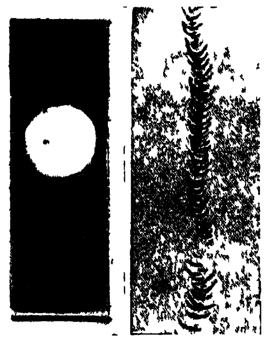
A MIGHTY CRANE WHICH DOES THE WORK OF HUNDREDS OF MEN

In ancient civilisations men worked like ants together, enslaved in tens of thousands. A hundred thousand slaves are said to have built the Great Pyramid. The despotism which massed men like ants has passed away, and in the modern world the power of thousands of men is put into a single machine

The photograph of the Titan crane is reproduced by courtesy of Messrs Stothert and Pitt, Bath

the microscope, nobody took the slightest notice of his discovery.

It is true that, in the reign of Elizabeth, another Englishman, Leonard Digges, chanced to read Roger Bacon's work, and made a telescope in accordance with the principles of the great, neglected man of science, but the instrument was only regarded as a curious toy. About the beginning of the seventeenth century, however, some spectacle-makers in Holland were moved by a stronger and larger passion of inquiry. The spirit of modern science had just been born, and the Janssens of Middelburg were affected by it. Instead of keeping to spectacle-making, they began experimenting with the lenses they were polishing; in 1598 they invented the modern microscope, and in 1608 another optician of the same town constructed the telescope. A year later Galileo was sweeping the skies with the new tube, and finding the satellites of the planet Jupiter.



WHAT NO EYE CAN SEE

The left photograph is of a microscopic slide as it appears to the eye; on the right is a photograph of a portion of the slide taken with a microscope, showing a host of living bacteria.

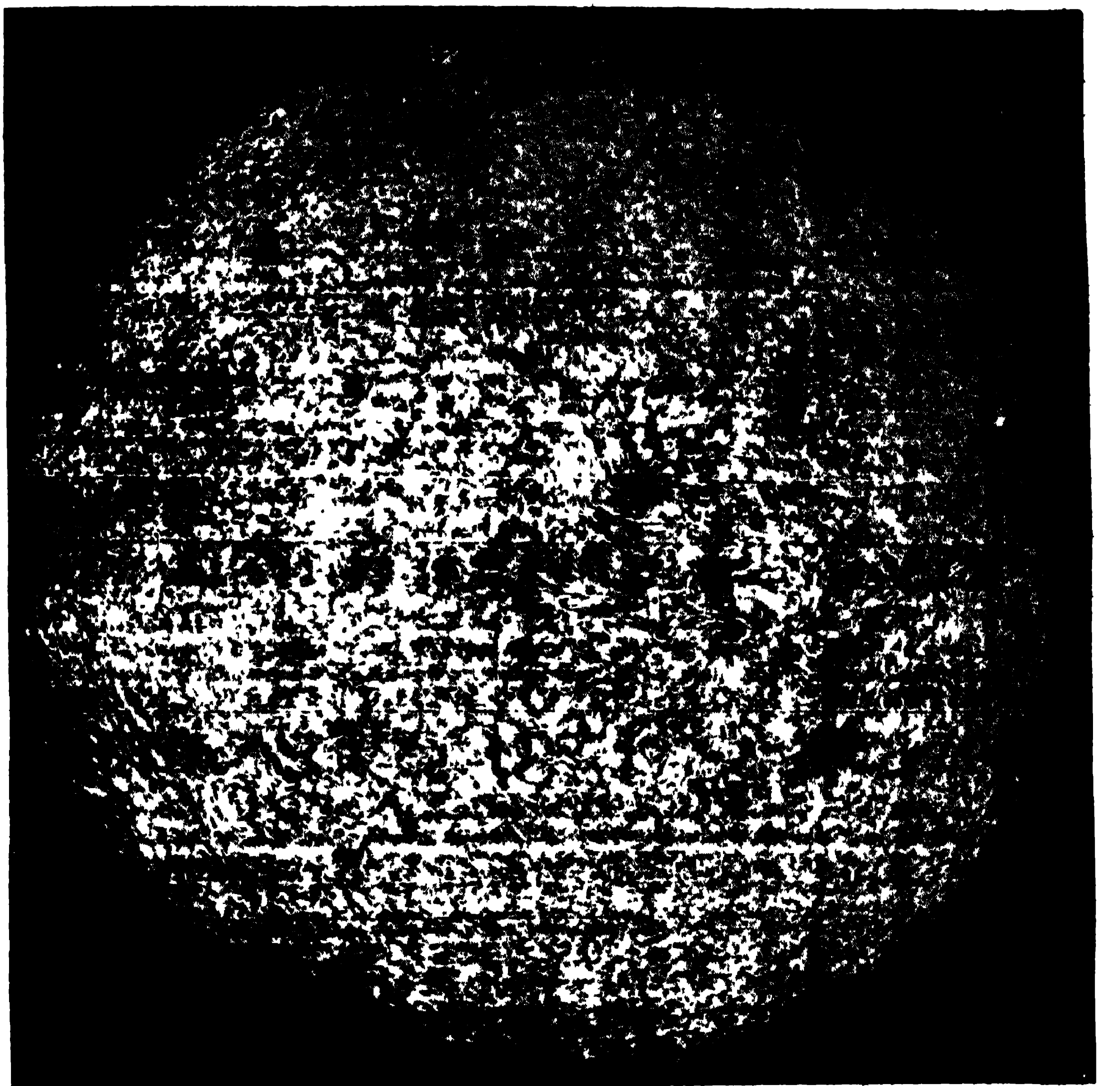
The simple instrument that Galileo used has now been elaborated into an enormous and intricate thing. At Mount Wilson, in California, there is a telescope with an aperture of sixty inches. The glass disc weighs a ton, and it forms the chief part of the largest instrument of vision in the world. But already it is regarded as too small, and a rich American has presented a considerable sum of money for the erection of a still vaster instrument. The new telescope will have a glass disc one hundred inches in diameter, thirteen inches thick, and with a weight of four and a half tons. In the old days telescopes were built with an extraordinary length of tube; some of them reached six hundred feet into the sky. Better effects are now obtained by increasing the breadth of the instrument. The difficulties of casting tremendous glass discs, and of obviating the distortions produced by changes of temperature, are very great; and very great, also, is the difficulty of providing mountings to carry the huge lenses with the necessary precision. With each new improvement in manufacture, however, the size of the modern telescope increases. Yet this in itself would not greatly add to our knowledge of the elements of the stars. The larger the telescope, the smaller the stars appear. This, of course, is not true of the sun, the moon, or the planets. With each increase in the diameter of a telescope, the structure of these heavenly bodies can be studied in more detail. The stars, however, are so inconceivably remote that no telescope can reveal their shape. They are mere flicks of light which show more minute and point-like as the power of the telescope increases. Their apparent discs appear large in small telescopes, and small in large instruments. All that the Snow telescope on Mount Wilson does is to make the stars seem smaller in size and more distinct from each other.

It was not, therefore, by means of any telescope that man found out what the stars were made of. Neither was it by means of the telescope that Sir Norman Lockyer discovered in 1868 in the sun the new element of helium, which Sir William Ramsay found again in 1895 in cleveite, a Norwegian mineral, and afterwards in the mysterious substance of radium.

MATCHES PHOTOGRAPHED THROUGH THE BOX BY X-RAYS

This marvellous achievement ranks among the greatest triumphs of modern astronomy. Nothing is so calculated to display the almost supernatural extension of the senses of man as the fact that he is able to trace a new element in the flaming sun twenty-seven years before he chances to find it on the earth. All this was the indirect result of an experiment which was announced in 1672 by Sir Isaac Newton, sixty-three years after Galileo first swept the heavens with a telescope. Newton admitted a thin ray of sunlight through a narrow slit into a dark room, so that the light fell upon a piece of three-sided glass. The prism of glass split up the white ray and reflected it in a band of rainbow colours. As it is well known, whiteness is composed of a mixture of all colours. These

colours represent the various lengths of waves in which light travels in its passage through the ether. Red waves, for instance, are about 1-39,000th of an inch long, while violet waves are about 1-60,000th of an inch long. In passing through the prism of glass, these waves are sorted out into a rainbow band, or spectrum. An ordinary rainbow is formed in somewhat the same way by sunlight falling on raindrops.



A PHOTOGRAPH OF THE SUN, SHOWING SOME OF THE STUFF IT IS MADE OF

This remarkable direct photograph of the sun was taken at the famous sun observatory at Mount Wilson, California, by Professor Hale. By a marvellous adjustment of instruments, the telescopic camera was made to "see into the sun," as it were. What we see in this photograph—technically called a spectro-heliogram—is really a mass of clouds of calcium vapour, which are invisible to the eve, even through the best telescope. The dark patches are sun-spots.

By taking the rainbow out of the skies and placing it in the laboratories of science, Newton gave mankind an instrument more wonderful than the telescope. By means of it man is now able to penetrate into the flaming mass of a star, billions of miles away, and discover what it is made of. It is pleasant to find that an Englishman, Sir William Huggins, has been the pioneer in this marvellous work. From the private observatory which he built at Tulse Hill he has gone forth, night after night, for more than fifty years, on mining explorations among comets and meteors, star-mists and stars.

This is surely the longest and most wonderful flight of the human mind. Yet the means by which it is done are very simple. A German man of science, G. R. Kirchhoff, discovered them about the middle of the nineteenth century. He used a lantern throwing out a ray of limelight; this ray was broken

up on a prism and thrown on the wall in a band of colour. Kirchhoff placed a lighted lamp before the ray from the lantern, and put a little salt into the flame of the lamp. Now, salt burns with a yellow light; and Kirchhoff expected that, on mixing this yellow light with the white ray from the lantern, he would deepen the yellow part of the spectrum. But, to his intense surprise, he saw a dark line start out where the bright yellow line should have come.

The Wonderful Map that Men have Made of the Light of the Sun

A curious thing had occurred. The light from the lantern was hot, and the light of the lamp in which the salt was burned was much cooler. When the yellow waves from the lantern reached the yellow waves in the lamp, they expended all their energy in heating up to their own temperature the waves coming from the burning salt. The first yellow waves were absorbed on their journey; consequently there was a blank, empty space in that part of the spectrum where they should have been.

This is what happens in our sun and in every star. At the centre is a mass burning at an extraordinary heat. From this burning mass arise enormous clouds of flaming vapour. These clouds, however, are cooler than the central heart of fire. So every hot wave of light from the elements flaming in the furnace is absorbed by the corresponding but cooler wave coming from the vapour. That is why the spectrum of the sun or a star is composed of a band of colours streaked with dark lines. Nearly all these lines have now been mapped out according to the elements which they represent. By letting the light of a certain star fall on the spectroscope, the astronomer is able to tell from the colours and lines exactly what the star is made of.

The Astonishing Power of the Spectroscope, which Breaks up Light

A chemist analyses substances in the same way. In 1895 Sir William Ramsay was analysing the mineral cleveite. He burnt it in a very hot furnace and turned it into gas, and examined this gas through a spectroscope. He found that it gave a yellow line in that part of the spectrum which is called D3, near the yellow lines made by the ray from burning salt with which Kirchhoff had experimented. Now, this D3 yellow line had been discovered by Sir Norman Lockyer in 1868 while examining the highest and most vaporous prominences of the sun. Thus by means of the spectrum the marvellous double discovery of helium was made, and it has again been found by recent spectroscopic study in the emanation of radium.

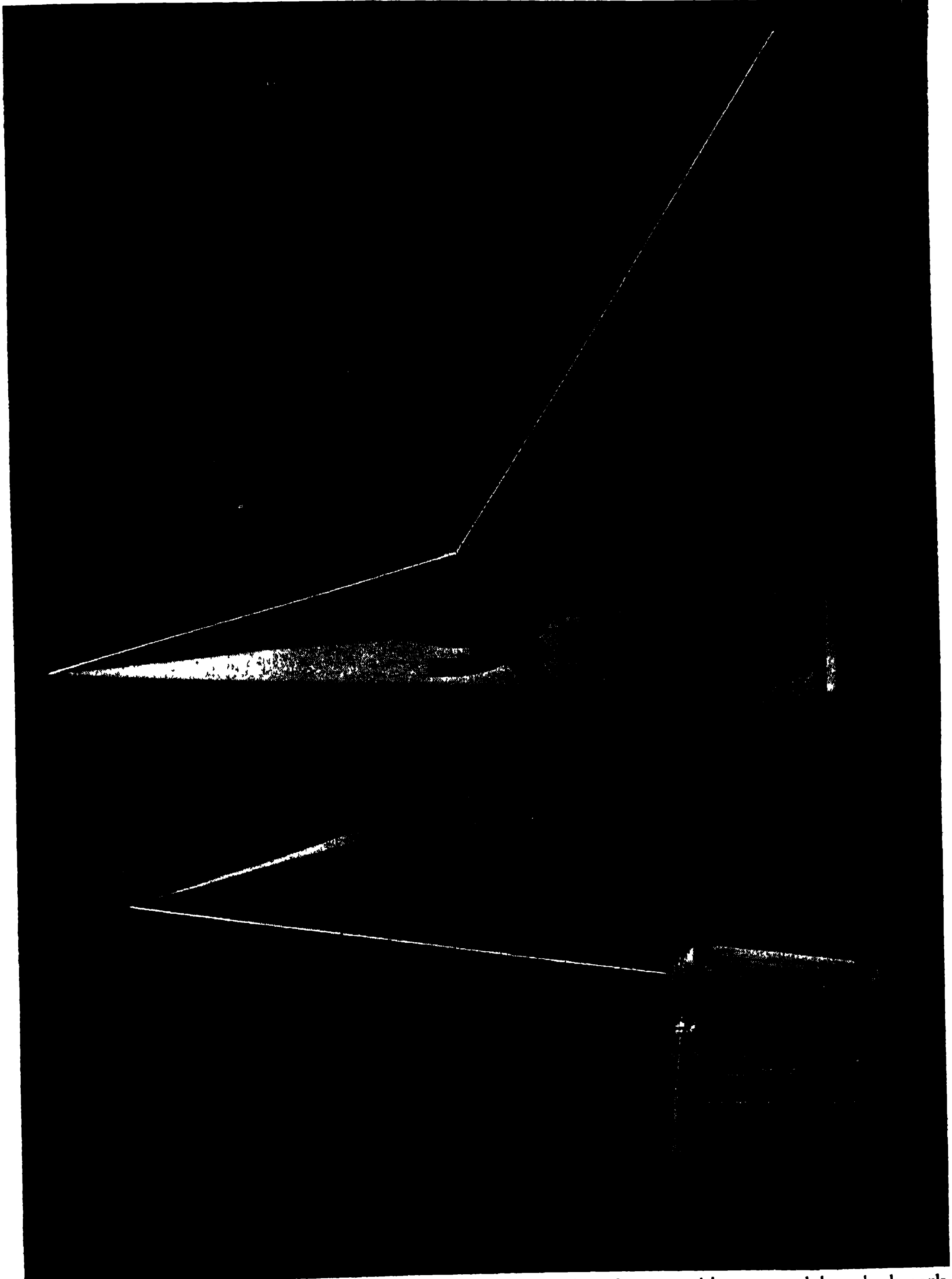
The modern spectroscope is perhaps the most wonderful instrument of modern science, in regard both to its power and to the skill necessary in making it. The prism of glass is no longer used for the most delicate investigations. Its place is taken by a simple-looking piece of bronze, with an apparently slightly rough surface. That slightly rough surface represents the very highest reach of human ingenuity and mechanical skill. It is formed of lines ruled by the finest point that can be put on a diamond. If during the operation the point of the diamond is in the least way worn, the piece of bronze is useless. The lines must be accurately spaced, and ruled from fifteen thousand to twenty thousand to the inch! The work is done by a machine invented by Professor H. A. Rowland, and placed in a constant temperature in an underground vault in the Johns Hopkins University. The screw, which moves the plate forward by 1-15,000th of an inch between the strokes of the diamond, contains almost no errors; and the effect of the exceedingly minute irregularities is compensated by ingenious devices that form part of the ruling-engine.

The Tremendous Band of Light which our Eyes Cannot See

The machine is automatic in its action. When it is set in motion the ruling of a large spectroscope goes on without interruption for six days and nights. By ruling the lines on a concave piece of bronze, the spectroscope is made so that it acts without any telescope. The ray of light falls through a slot in the roof of the observatory directly on the concave piece of bronze, and a spectrum is formed which can be examined by the eye, or photographed for further study.

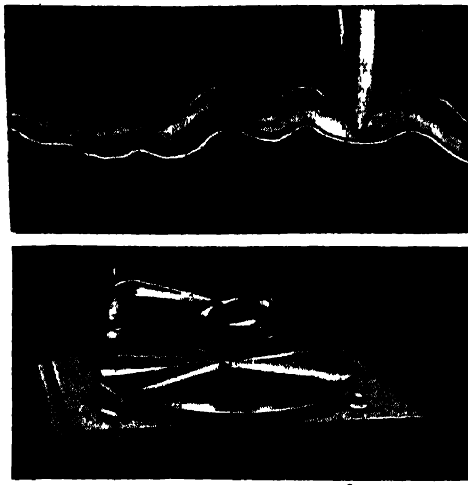
The spectroscope is especially interesting for its strange revelation of the gross defects of the human eye. The telescope and the microscope flatter us; they merely prolong and magnify our actual power of vision. By means of them, we only add more lenses to the lenses of our eyes, and so increase our natural sight. The spectrum produced by the spectroscope teaches us, however, that we are almost sightless. On either side of the small fragment of colours which the human eye discerns in the spectrum, stretch long bands of invisible hues. Some of these represent waves of light too long for us to see; others are produced by waves too short to make any

FINDING OUT WHAT A STAR IS MADE OF



As a star travels across the sky, its ray is caught on a glass plate by a machine moved by clockwork, so as to keep in the track of the heavenly body. From the glass plate the ray is reflected on to a spectroscope—a concave piece of bronze. This is ruled with fine lines, which break the ray of light into a band of colours, and this band is called a spectrum. The spectroscope throws the colours on a screen, so that they may be easily studied. The astronomer often burns some known substance in a retort, and throws its spectrum also on the screen, as shown here, to compare with the analysis of the star.

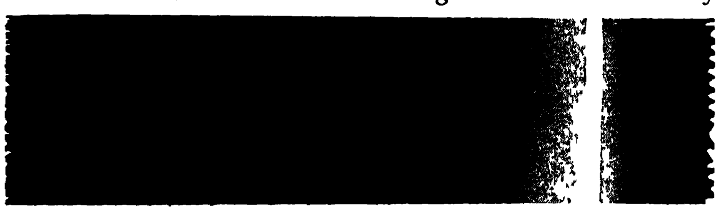
effect upon our eyes. Only an exceedingly small part of light is translated by us into vision. Beyond the real rays of the rainbow-like spectrum, extends an unseen colour, called ultra-red. Its existence was not discovered until 1800, when Sir William Herschell held a thermometer there. Beyond the violet end of the spectrum is another invisible kind of ray—the ultra-violet ray—which J. W. Ritter found in 1801, by placing a sort of photographic paper at the lower end of the spectrum.



THE INVENTION WHICH IMMORTALISES THE HUMAN VOICE

The top picture shows a gramophone needle, much magnified, travelling in the grooves made by vibrations of air produced by the human voice. The needle moves round the disc so creating another series of sound-waves exactly similar, and in this way reproducing the voice.

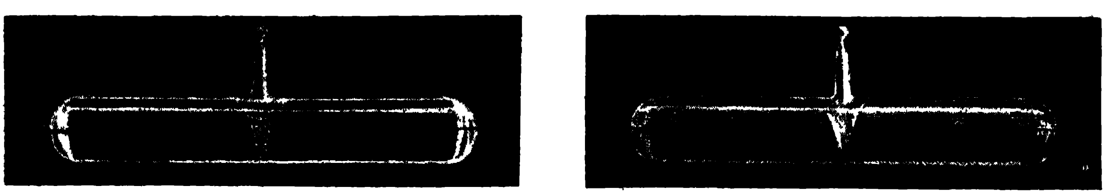
If the evolution of the physical powers of man is not at an end, there might possibly be evolved a race who would be able to see by means of the ultra-red rays of light. To such a race ordinary sunlight would be as useful as it is to us; for there are all kinds of rays in the sunshine. But the new race would also be able to sit in an absolutely dark room, warmed by hot-water pipes, and see and read there as well as we can do by gas-light. Their windows might be made of thin plates of hard rubber, and yet let the light through to them; and they could study the sun with telescopes fitted with lenses of the same hard, dark material. Perhaps creatures may exist somewhere in the universe with the strange power of seeing only with the ultra-red rays that remain invisible to us. If, however, such creatures are to be found, they are likely to possess certain disadvantages of vision. What these disadvantages are, science is able to show us by actual experiment. By employing a screen which admits only ultra-red rays into a camera, and by preparing a special photographic plate, it is now possible to obtain a picture of the world as it would appear to creatures who see only with the long waves of the invisible red rays of light. In an ultra-red photograph the blue daylight sky appears as black as night, and the trees show white, as though the foliage were dusted with snow. This curious inversion of natural colour is due to the fact that the blue and violet waves of light are excluded by the ultra-red screen.



THE LIGHT BY WHICH WE SEE THE WORLD

Our eyes look out upon the world by means of waves of light from the sun, but our eyes see light-waves of only a certain length. Other waves of light are invisible to us, though we know of them and can photograph by them or even measure them. This black block represents all the light-rays that we *know* to exist, and the thin white line represents the light by which we see.

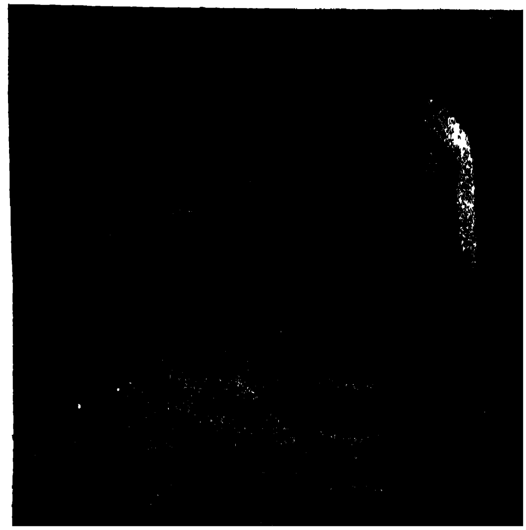
In an ordinary good photograph, little or none of the light that we see is used in printing the image of natural objects. Here the other invisible end of the spectrum—the ultra-violet ray end—comes into play. By means of a screen of quartz, one can cut off all visible light from a camera, and exclude the ultra-red rays as well, and still take photographs as usual. The



THE LITTLE INSTRUMENT WHICH MAKES WIRELESS TELEGRAPHY POSSIBLE

We send a wireless telegram by means of faint rays in the ether—so faint that at one time science knew no means of "picking them up." Then the "coherer" was invented, the instrument here shown, a tiny glass tube, in which are two silver plugs. Between the plugs is a little space where lie loose grains of nickel and silver. It is these filings which "pick up" the waves and cohere, or join together, so completing a circuit and making wireless telegraphy possible.

invisible world of the ultra-violet ray has been explored by means of the delicate salts used in photography. Ultra-violet rays



THE MAN WITHOUT A SHADOW—A GREAT CONCEPTION IN FICTION MADE TRUE BY SCIENCE

A famous story of last century had for its central character a man without a shadow. These two photographs, taken practically at the same moment, show the shadowless man in fact, though no eye has ever seen him. The second picture was taken by means of ultra violet rays of light, invisible to the eye, which passed through the shadow

possess some extraordinary powers. Had they been known three or four centuries ago, the alchemists would have fancied they had found the philosopher's stone, for these rays will turn one kind of phosphorus into quite a different kind; they will produce violent explosions; and make some substances give out light without producing any heat. They also have some wonderful healing properties. Certain cancerous growths disappear under their influence, and so do various skin diseases. It is the invisible violet ray which works in the green leaves of plants, and turns carbonic acid and water into sugars and starches. As this is the first step towards the organisation of life, it will be seen that the subtle action of the wonderful unseen violet ray is of tremendous importance to us.

A PHOTOGRAPH TAKEN BY INVISIBLE LIGHT

ence is in the length of the light-waves, the eye being able to use only waves of certain lengths. This photograph was taken in a quarry in Syracuse, by means of infra-red light-waves, which are too long for the eye to see.

The ultra-violet rays shine through many substances impervious to visible light. Thus, if creatures existed with eyes attuned to these short waves of light, they might also live in rooms as black as ink to us. Perhaps it might be thought that, though these two invisible worlds of light may exist, man does not lose much by being excluded from them. Well, let us make a few calculations. Men of science have taken the unit of microscopic measurements to be the millionth of a millimetre—a millimetre being equal to about 1-25th of an inch. The wave-length of the longest known ultra-red ray is, according to Professor S. P. Langley, 1-16,500th of an inch; the shortest known ultra-violet ray is 1-32,500,000th of an inch. Our eyes, however, cannot perceive a wave of light longer than 1-32,600th of an inch, or shorter than 1-62,850th of an inch. Our sense of light is the chief and most highly developed of our

senses; it is the main avenue of knowledge to our intellect, yet it is terribly defective.

But, after all, the mind of man is at last able to fashion instruments by which it can penetrate into the invisible worlds around it. By means of the microscope new forms of infinitesimal life are now being constantly discovered. The first microbe was seen by a Dutchman, A. van Leeuwenhoek, in the seventeenth century, but not until Pasteur arrived was the study of the minutest of organisms conducted in a scientific manner. Strange as it may seem, the microscope is not, in spite of its wonderful power, the chief instrument in the discovery of the disease-producing microbe.

Many of these invisible armies of death cannot be seen under the most perfect of modern microscopes. The limits of visibility with the microscope have been very carefully measured, and they are found to range from a hundred-thousandth to about two-hundred-thousandth of an inch.

The Armies of Death which no Microscope can Reveal

As under this magnification the outline grows very dim, many comparatively visible objects cannot be distinguished. In these circumstances, it is necessary to invent some colour which will stain the microbe with a colour different from the hue of its surroundings. This could not be done until the dyes made from coal-tar were carefully examined; and even at the present day there are many disease-producing microbes which are well known from their effects, but which cannot be stained and made visible. Some of them are fairly large, for they do not get through a filter; yet, until some means of staining them is discovered, they cannot be studied with a view to protecting mankind from their attack.

In regard to its extraordinary fine power of measurement, the interferometer is far more important than the best miscroscope. By means of the interferometer an observer is able to detect a movement through one-five-millionth of an inch! The principle on which Professor Michelson, of Chicago University, constructed this instrument is very simple. The machine uses the minute lengths of waves of light. If two pebbles are dropped in a pond, say a yard apart, two systems of waves ripple out in circles. When the waves from the two systems meet, a varying effect is produced. If the crests of one set of ripples coincide with the depressions from the other set, the water in that particular spot becomes smooth. The waves, then, interfere, and one set destroys the other. If, on the other hand, the crests of waves from the two sources coincide, the crests rise to twice their original height. The interferometer uses light-waves sent out from two points, like the ripples produced by dropping two pebbles in the pond. The two sets of light-waves either interfere and produce darkness, or unite and produce light of double brilliancy. These alternate bright and dark bands are technically called interference fringes.

How Men Measure a Five-millionth Part of an Inch

Such is the theory. Now let us attempt to explain how it is worked out in practice. A beam of light falls on a lens which makes all its rays approximately parallel. The beam is then directed on to plate glass; the plate glass divides it into two beams. Each beam is reflected on to a separate mirror; each mirror, again, reflects its beam in such a way that the two beams meet, like the two sets of ripples in the pond. The waves of light then either interfere or coincide; they produce either darkness or more brilliancy; and the effect is easily observed through a tube. Every part of the instrument is exquisitely finished and adjusted, and responds to infinitely delicate alterations. The heat of a hand near one of the beams makes a new pattern in the interferences; a lighted match creates a wild storm among the minute waves of light. The interferometer is now often used in measuring the very high temperatures of blast-furnaces.

By means of this marvellous instrument Professor Michelson has made a notable experiment in determining the force of gravitation. He measured the amount of attraction which a sphere of lead, eight inches in diameter, exerted on a small ball hung on the arm of a delicate balance. The force to be measured was 1-20,000,000th of the weight of this small ball, and it produced in the interferometer a displacement of seven fringes of the light-waves.

The Way in which the Earth was Weighed at Birmingham

The American professor could easily weigh the earth by means of his wonderful little invention, but this had already been done by Professor J. H. Poynting, of Birmingham, by another very ingenious method. We cannot weigh the earth in the ordinary way; we cannot apply to it our ordinary measurements of weight. Our tons and hundredweights and pounds are only measures of the force of gravitation which the mass of the earth exerts on objects on its

surface. The earth cannot pull itself to itself, and thus, in the everyday sense of the term, our planet has no weight at all. Moreover, though we can estimate the size of the earth, we cannot say how much of it is heavy substance and how much is light. We do not know, in short, how dense it is, but—and here is the miracle—we can find out this. For it is now possible to measure what all the heavy rocks and lighter elements *weigh in the mass*—that is to say, we can find out their general density, when they are contrasted with a globe of the same size composed of water.

The Pull on a Spring Balance by a Force 4000 Miles Away

We know a cubic foot of water weighs about 62½lb. If we knew what a cubic foot of the general mass of earth weighed compared with the density of water, we could calculate the weight of a globe 7912 miles in diameter.

Thus the process of weighing the earth consists in finding its mean density; and water, which is said to have a density of one, is taken as a standard substance. Professor Poynting discovered that the density of the earth was about 5·4934.

And this is how he did it. He hung two leaden weights, weighing fifty pounds each, at the end of a large spring balance a few feet above the earth. The pull of the earth was then fifty pounds; and it was exerting this pull with its centre about four thousand miles, or twenty million feet, away. Under the balance where the two weights hung, Professor Poynting placed a heavy mass of lead weighing about three hundred and fifty pounds. It was set on a turn-table, so that it could be moved from one fifty-pound balance weight to the other fifty-pound balance weight. The three hundred and fifty pounds of lead rested one foot away from the first fifty-pound weight, and by gravitation that weight was attracted to it.

How We Know that the Earth Weighs Six Billion Trillion Tons

To the fifty-pounds pull which the vast mass of the earth exerted on the fifty-pound weight, there was now added an infinitesimal additional weight created by the gravitation pull of the mass of lead on the turn-table. The fifty-pound weight, in short, now weighed about 1-250th of a grain more. Figuring all this out, it appeared that the pull of a 350-pound weight, at the distance of a foot, was equal to 1-250th of a grain, or 1-1,750,000th of a pound—that is to say, the pull of the earth at a distance of twenty million feet was about a hundred million times as great as that of a sphere of 350 pounds at one foot. If the earth could be placed at an average distance of one foot from the fifty-pound weight, instead of at a distance of twenty million feet, its pull would be proportionately greater—about four hundred trillion times greater; so that at equal distances the pull of the earth would be *four hundred trillion times* that of a hundred million 350-pound spheres. But, as already explained, at equal distances these pulls are proportional to the masses concerned, and thus, by doing a little more arithmetic, it has been found that the earth weighs about 12,500,000,000,000,000,000,000,000 pounds, or about six billion trillion tons. A billion is here reckoned as a thousand millions, a trillion as a million millions.

In the actual experiment the balance was placed in the cellar of Mason College, Birmingham, and a mirror was connected with the balance pointer. This mirror was so arranged as to magnify a hundred and fifty times the movement of the balance beam. Through a small hole in the ceiling of the cellar a telescope was fixed, and in the room above Professor Poynting watched the balance through the telescope. So delicate was the apparatus that if anyone walked about the house Professor Poynting was unable to carry on his work. The step caused the mirror to quiver, and interfered with the reflection of a scale which was studied by means of the telescope.

One Boy's Weight which Might Upset the Weight of all Great Britain

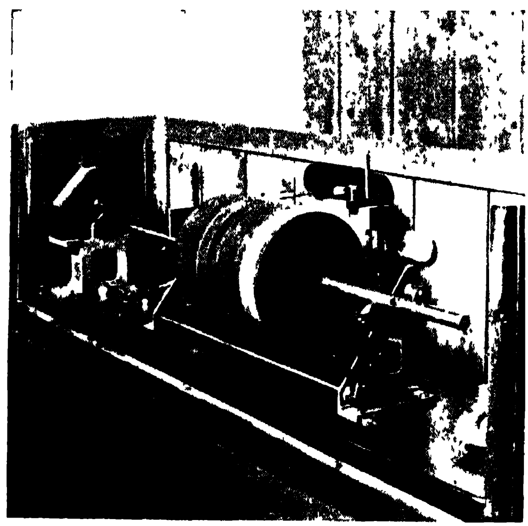
This difficulty was overcome by placing the instrument on great blocks of india-rubber, and the balance then worked well for a year, but it began to go wrong, owing to the floor of the cellar tilting whenever Professor Poynting moved the 350 pounds of lead from one side of the balance to the other. The tilt was so slight that, had the floor been ten miles long, one end of it would have been raised only one inch higher than the other end ten miles distant, yet this minute disturbance seriously affected the professor's observations. Gradually all difficulties were overcome, and he calculated the density of the earth to be 5·4934, compared with the density of water as one.

Suppose all the inhabitants of the British Isles, say forty million persons, were placed in one pan of a gigantic pair of scales, and that they were counterpoised by weights, do you think the addition of one middle-sized boy to the population of the scale pan would be observed by the man who was weighing them? That is the sort

THE WORK OF AN EARTHQUAKE IN JAPAN

of difference that had to be measured — a difference of one part in seventy or eighty million parts. Or perhaps it would be more correct to say that the degree of perfection to which the art of weighing was brought by Professor Poynting was such as would be required to detect, in this imaginary experiment, whether the boy had both his boots on!

In measurements of this sort, the operations are of so delicate a character that the passage of a railway train in the neighbourhood may be a grave source of trouble. In the year 1894 Professor C. V. Boys was working at Oxford on the same problem of the density of the earth. He was using the astonishing threads which are made of melted quartz. These are incomparably finer than the finest wire. A single grain of sand, spun into one of them, might yield a thread a thousand miles long. These threads surpass steel in strength, and they are marvellously elastic. Armed with them, Professor Boys was able to make what is probably the best measurement yet obtained of the mean density of the earth: he fixed it at 5·5270. In the midst of his measurements, however, there was a mysterious disturbance. An earthquake was taking place some thousands of miles away! It was detected at Oxford, owing to the fact that Professor Boys was weighing the earth when the wave from the far-off upheaval travelled through the solid ground and shook his instrument violently.



THE MACHINE BY WHICH AN EARTHQUAKE "WRITES"

The seismograph is an automatic recorder of earthquakes, so sensitive that the slightest tremor of the earth is registered. Light falls on a roll of photographic paper through a slit in a metal plate, making a thin line on the paper. The vibration moves the slit so that the line wobbles up and down; and the extent of the wobble indicates the nature of the shock.

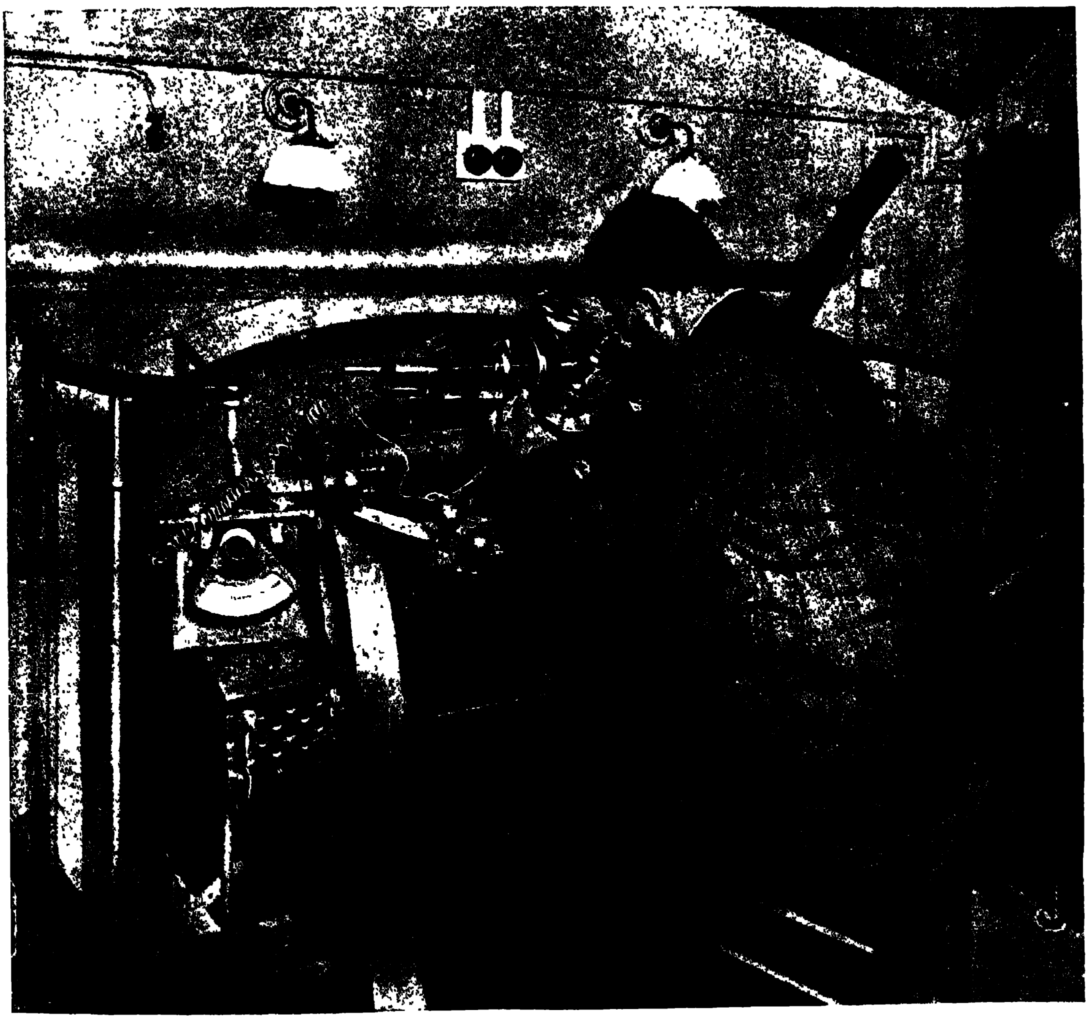
If this instrument were used to mark the occurrence of an earthquake, it would be called a seismoscope. But seismoscopes are not employed nowadays. They belong to the infancy of the science of earthquake study. What the modern man of science needs is an automatic recorder, which, in response to the slightest tremor of the ground, will write down or photograph all the curves of the movement. This is called a seismograph. In principle it looks like a mast with a boom jutting from the base. At the far end of the boom is a thin metal plate with a slit in it. Beneath the slit is a box carrying a roll of photographic paper, driven by clock work. At the top of the box is another slit, immediately underneath the slit on the boom-plate. A beam of light falls through both slits on to the photographic paper, and prints on it a sinuous

THE RECORD MADE BY AN EARTHQUAKE

line. Every vibration of the earth causes the boom to move; the position of the slit at the end is then altered, and the line printed on the photographic paper wobbles up and down.

The study of earthquakes strikes the imagination chiefly by reason of the strange, terrible, and disastrous power that bursts out in the great catastrophes of our planet. vibrations due to the traffic in a city compare with it as the waves of the ocean with the ripples on a pool.

Two types of short waves are frequently observed. One has been traced to the action of the wind, which is found to create waves in the land just as it forms waves in the sea. A still smaller vibration, which occurs every five or ten seconds, appears to be due



MEASURING THE TEMPERATURE OF A STAR

By examining the spectrum of a star an astronomer can tell of what elements the star is composed. By experiment in the laboratory he can determine exactly the amount of heat necessary to convert various substances into light-giving gases, and he can examine their spectra. When he sees in the spectrum of a star the elements which are transformed into gases at a low temperature, he knows that the star is not very hot. Hot stars are violet, indigo, and blue in colour; cool stars are yellow, orange, and red.

The man of science, however, is but little interested in the largeness of the tremors of the earth. The small waves running through our apparently solid soil now seem to him to throw more light on the great problems than do the fierce shocks of some wild and sudden upheaval. At the present time he is mainly concerned in tracing movements of the earth so small that the to the impact of billows on the shores of the earth; and experiments are now being carried out on the coast of Northumberland by means of an extraordinarily delicate instrument. It works automatically. The almost imperceptible pressure on the air which a wave of the sea produces, as it travels to the land, is transmitted by an electrical arrangement to a pen. The pen

writes out the record of the pressures on a strip of paper and when it has filled a page it automatically returns to its original position and starts writing off a new sheet So exquisitely balanced are the finest earthquake measurers that they are thought to be able to record dim waves in the ground representing the echoes of great earthquake shocks that originated a century ago

Measuring the Heat of a Candle a Mile and a Half Away

Is not all this a wonderful extension of our naturally dull sense of the movements around us? Our sense of heat has now become almost as fine as our sense of movement By means of the bolometer for instance there can be felt the heat of a candle at a distance of a mile and a half The instrument consists of two very fine threads of platinum about a 2500th part of an inch thick One of these threads is protected in a constant-temperature chamber, the other is exposed to the radiation which it is desired to measure Connected with the two threads is a galvanic battery, on the battery are fixed a needle and a tiny mirror If the mirror moves it reflects a spot of light on a photographic plate Now by a device known as the "Wheatstone Bridge" a current of electricity flows in a wire running round the battery and connected with the two threads of platinum But this strong current is so regulated by the position of the two platinum threads that it does not flow into the galvanic battery An absolutely imperceptible movement of the thread however allows some of the current to pass and there is then an imperceptible movement of the needle This is magnified into a wobble by the spot of light reflected from the tiny mirror and the photographic plate records the disturbance

In this case the use of photography is very important No doubt, it would be possible to obtain a rough measurement of the effect merely by watching the spot of light move across a wall

The New Eye of Man which Follows the Track of a Star

But the photograph enables the man of science to make exact measurements in daylight Having developed the plate he can scrutinise it under a powerful microscope with a resolving power of a hundred thousand lines to the inch Thus he is able to trace the effect of the heat of a single candle a mile and a half away from the platinum thread of the bolometer.

The development of photography has had many happy effects on several branches of science The camera is a new eye, with a superhuman steadiness and strength Placed at the end of a telescope it watches the sky without growing weary or distracted Following the track of a star so remote that its ray falls through the abyss of heaven with a faintness making it invisible to the most powerful telescope the camera slowly collects the dim light, hour after hour and reveals at last to the astonished astronomer a new sun

A brief comparison will help us to appreciate what the camera has done for only one branch of science Let us leave out of consideration the very useful part it plays in photo microscopy and other methods of minute measurement We will take only photo-telescopy A keen-sighted observer might count with his naked eye two thousand stars—or a few more—in an exceptionally clear sky at night The finest telescope reveals tens of hundreds of thousands of points of light Now with the aid of the camera and the ultra-violet rays there is being made an international star-map which will definitely show the position of about thirty million stars

How the Mind of Man Peered Beyond His Senses

In the great wireless telegraphy stations in which messages are received from points thousands of miles distant the photographic plate has recently been found to be indispensable By means of it the marvellous work of Marconi has been made a practical success The signals are now sent at so high a rate of speed that no operator could read them by sound or sight So a galvanic battery is connected with the receiving apparatus and the movements of a filament are reflected and photographed upon a sensitive strip of paper which winds along at a suitable rate of motion

Attached to the galvanic battery is another wonderful magnification of the human senses Perhaps it would be more correct to say that it is a new sense rather than the magnification of any existing power of mankind It is sometimes called a detector and sometimes a coherer Its function is to detect the ripple of electric force which is the agent in wireless telegraphy

The existence of electric waves was known before they were discovered This is one of the instances in which the human mind was able to anticipate the evidence of its senses In 1864 sufficient facts had been collected to enable Clerk Maxwell to draw

out a theory of electric waves: and the waves were found by Hertz in 1888. Hertz produced electric sparks, and made these sparks shoot backwards and forwards between two sheets of metal. At every to-and-fro movement of the sparks an electric wave was sent off; and by touching with a key the door-knob and other pieces of metal anywhere about the room, new sparks could be obtained. This had already been done by Professor Silvanus Thompson, who, in 1874, had made a detector with two door-keys, and had walked about the room collecting sparks.

It never occurred to the English man of science, however, that the existence of the new sparks showed that electricity had been given off in the form of waves. Hertz used his detector—a bit of wire bent into a ring so that the two ends nearly met--to measure the places where the electric sparks could be obtained apparently from the air — though really from the ether. By this means he measured the wave lengths. He then showed that they were really waves—like the light-waves—by reflecting them in new directions by mirrors. Thus the idea of wireless telegraphy was born.

The Great Discovery that Made Wireless Telegraphy Possible

But the electric waves could not be used to transmit signals over any large distance. As they went out in long and longer ripples in the ether, they became too feeble to be detected by any existing instrument. So men had to invent a new sense. A great French man of science —Professor Branly —thought out the difficult problem, and at last discovered the coherer. He found that certain metal filings resisted the passage of an electric current; when, however, an electric wave fell on the filings, they cohered, and allowed the electric current to pass. A wire connecting a battery to a bell was cut, and a tube containing some metal filings was inserted between the two ends of the wire. When the faint electric wave arrived, too weak to emit a spark or show its presence in any direct way, it was conducted to the filings. They then cohered, and the current from the battery rang a bell, or gave some other signal. Various forms of detectors have since been discovered; and it is owing to their extraordinary fineness of response that man is now able to make the electric wave carry his messages to the ends of the earth.

To Hertz, the discoverer of the electric wave, we are somewhat indebted for the still more marvellous creation of the X-ray. Pursuing the researches of Sir William Crookes, he sent a current of electricity through a glass tube which had been emptied of air. A strange ray —called the cathode ray— was produced at the cathode, or place where the current leaves the tube. Hertz found that the cathode ray had the power of passing through very thin metal films. Röntgen emptied the tube more completely of air than Hertz had done, and the current he then sent through it endowed mankind with a new power of vision.

The Magic X-Rays which Shine Through Solid Matter

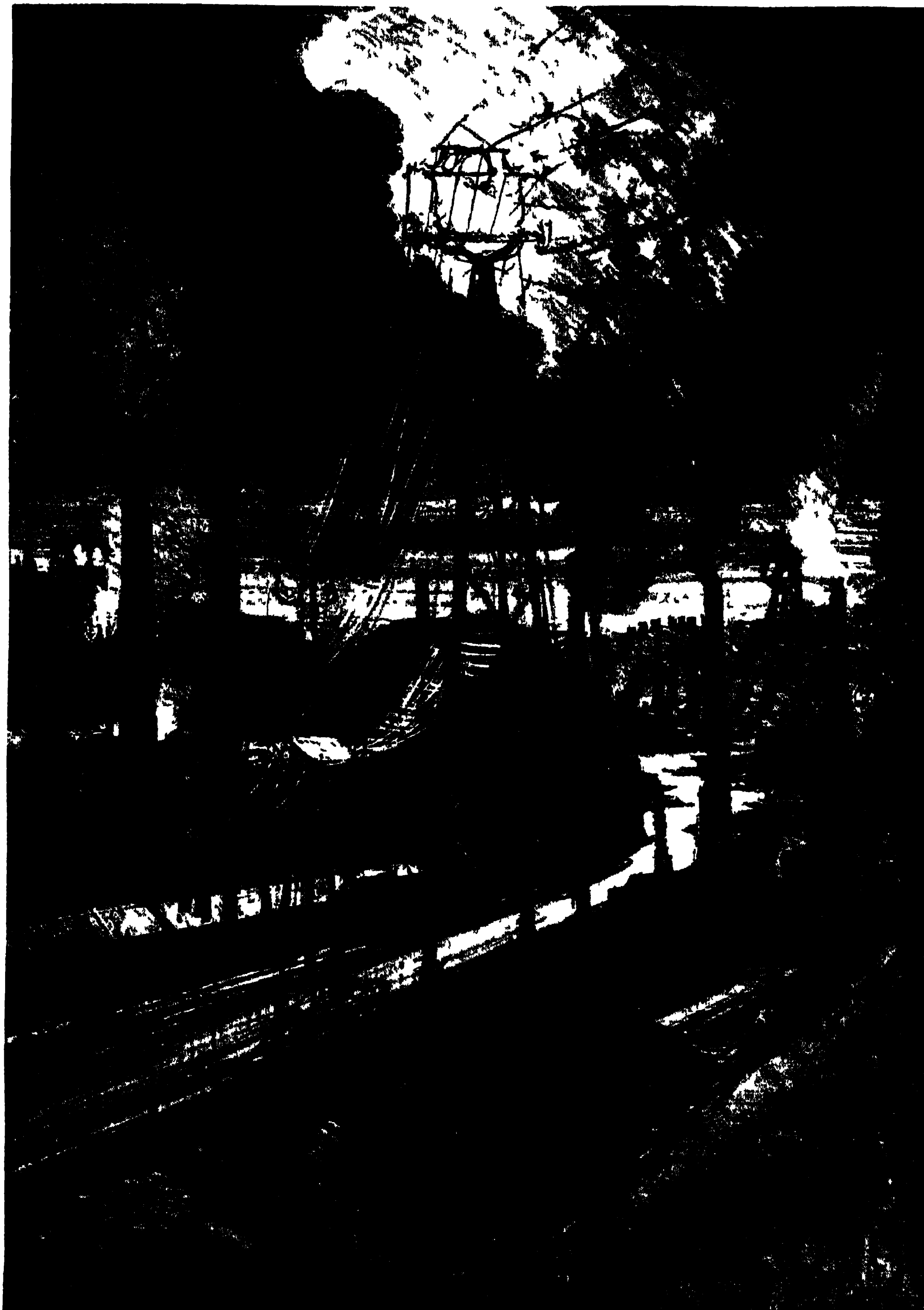
Thus was created the magic X-ray which shines through matter. It enabled man to peep, as through a crack in an enchanted door, into a universe of new wonders. In 1896, a few months after Röntgen announced his discovery, the door was flung wide open. Henri Becquerel in France and Silvanus Thompson in England found that uranium emitted an invisible ray; and, following out this indication, Madame Curie and her husband discovered the new element of radium, which is produced by the wasting away of uranium. When the nineteenth century closed, man stood with dazed and incredulous eyes, staring at the enormous power and the marvellous knowledge suddenly won.

He had to reconstruct the foundations of several of his chief sciences. Armed with the cathode ray, Sir J. J. Thomson broke up the atom, and showed that the ultimate form of matter was electricity; everything then became possible. A few months ago Sir J. J. Thomson again startled men of science by inventing an electrical method of analysing elements in a cathode tube and taking photographs of the rays.

The New Senses which Herald the New Age of Vital Power

Practically all the tremendous progress of modern knowledge has depended on the invention of exquisite and often small pieces of mechanism by which man has magnified his senses. We no longer have five senses—we have hundreds. With his five senses, man in the ancient civilisation could erect colossal works by lashing thousands of slaves to the task of dragging along huge masses of stone over wooden rollers. With our hundred senses we can set an iron slave to do more and better work than a host of serfs. Each little instrument we invent to measure something that we cannot see or hear, taste or touch, is a fresh source of power. When we learn to use our new powers fully, this age of transition will come to an end, and a new age of vital power will dawn.

AN ARTIST'S IMPRESSION OF THE STEEL CITY



THE PALL OF BLACK SMOKE THAT EVER HANGS OVER THE IRON WORKS OF CHARLEROI

This impressive study of the famous iron city of Belgium was made for "The World's Work" by Mr Joseph Pennell

STEEL AND CIVILISATION

The Life-history of the Material which has every Factory in the World and every Ship on the Sea at its Mercy

THE SKELETON OF THE WORKADAY WORLD

THE immeasurable progress of the world in industry and commerce during the last fifty years has depended, with increasing urgency, on the use in new ways of iron and steel. While it is true that this progress is directly due to man's control of power, generated through heat in various ways, or through electricity, his harnessing of this power for practical purposes would not have been possible if he had not found in steel a containing material, enduring, and minutely adaptable for all his growing needs.

We live in the steel age far more distinctively than men in the past lived in ages of stone or of bronze, for to-day steel is the one material on which man relies when he must have strength without great weight, the material through which his mechanical genius finds expression whenever it is using great power, the material on which he works, and from which he forms the tools for his work. We affirm, in short, and propose to prove, that it is the very foundation of modern industry.

Wood, stone, and clay were the first natural materials—apart from animal products—for man's makings and experiments, and when, accidentally, he discovered metals, he used them only to give himself a more rapid mastery over the abundant materials, ready to his hand, on which he then worked—the wood, the stone, the clay. So he built himself stone monuments which have retained their magnificence for thousands of years; wood-framed houses that remain after hundreds of years; and clay-reared paradises that have mouldered into the dust of deserts till the sites of the mightiest capitals of antiquity are only guessed at. The stern strength of the newly found metals served but to shape the perishable weakness of wood and stone and clay. Now all this is altered, for an inexhaustible substance has been discovered and perfected that is more shapeable than clay, stronger than stone, with qualities incomparably more varied than those of wood, furnishing material to work on, and the tools that will work itself, capable of taking every form of strength or of plasticity, pliable yet tough, rigid yet elastic, sharp yet soft as dough, hard to the bounds of human conception of hardness, and changeable to the last wish of the manipulator who knows its ways and sympathies. So steel, the multiform and multiplex, has become the mainspring of modern industry.

What is this new material with a thousand contradictory uses? What *is* steel? Of all the mixtures makable from the earth's contents, not one is more varied or elusive. Hundreds of observant experts spend their lives in studying its constituents, its combinations, its qualities, its possibilities, and they are unable to agree on a definition. Whatever definition is proposed, someone proves it to be wrong or inadequate. Iron, a metal never found pure in workable quantities, combines with carbon and other elements in varying proportions, and according to these proportions, which are infinitely graded, displays changing characteristics.

In certain of these proportions, and showing certain characteristics, it is called steel. Broadly, if its structure is fibrous, it is said to be iron; and if granular, steel. But the chemical constituents may be the same in each case, though the qualities of the mass for practical purposes are widely different. Iron, when spoken of distinctively as a marketable commodity, is the metal roughly smelted from its ore and combined with either much or extremely little carbon and various impurities; while steel is the iron remelted and purified by the loss of its carbon and various other elements, with fresh carbon to a moderate amount and known constituents

added, so as to bring the composition of the mixture under control, the ingredients and their proportions, and the characteristics of the combined mass in practical use, being clearly known.

The scientific tendency is to treat wrought iron and mild steel, each with a small proportion of carbon, as one; but common cast-iron, and also some of the steel alloys that are the last products of an inventive study, have large proportions of carbon, with sensationally different practical characters. Therefore, a proportion of carbon is not a satisfactory basis for definition, and it is better to treat all combinations of iron with other metals and carbon as one, understanding that commercial iron, or cast-iron used in manufactures, is the metal in its rough, cheap, less workable, less controlled condition; while steel is the higher grades of iron, with additions, after elaborate manipulations, which leave it less arbitrary, more adaptable, and better understood.

The most marvellous characteristic of steel is the variety, and, indeed, contrariety, of its practical qualities, with their infinite adaptation to man's requirements.

The Extraordinary Things that Can be Done with a Hundred Kinds of Steel

It can be forged into beams of enormous strength, or drawn out into wire of gossamer thinness; it can be compressed into a density that will resist any concussion, or be rolled into a thin sheet which may be hard or soft; it can be shaped by hammering, or cast in a mould; it can be given a rigidity of the utmost intensity, or be changed till the fingers of a child can bend it; it can be endowed almost with the hardness of a diamond, and receive an edge that will cut when it is white-hot. It can be as brittle as glass or as flexible as rope; can have a spring that will bend double and recover unhurt, or be as dead as lead; can be magnetic or non-magnetic, a conductor of electricity or a non-conductor. It can take some of these qualities, lose them, and regain them, according to the treatment given to it. All these kaleidoscopic qualities and changes are being studied with a scientific care and an enthusiasm unparalleled, in order that they may be known and fixed and made adaptable, under perfect control, for specific uses, because there are a hundred steels, each more suited than the rest for some particular purpose.

We may assume with confidence that steel was discovered by accident. Unquestionably it was used in the ancient world, and has been used to some extent for six thousand years, though little material evidence can remain from those distant days, owing to the tendency of all compounds with an iron basis to moulder away through rusting, or oxidisation, if exposed to damp.

The Discovery of the Material which is Revolutionising the World

We can see man in extremely early times, when not far removed from his primitive state, making his fire in a hollow surrounded by lumps of hard earth that chanced to contain iron and traces of the other metals commonly associated with it. The heat melts the metals till they run, and as they become fused they combine with carbon from the burning wood; and in proportion to the saturation of the iron with carbon, or the keenness of the draught that burns out the carbon and other elements in the ore, a workable lump of iron or accidental steel is formed. A natural step would be to plunge this lump of metal into water, as it passed from the molten to the heated state, so that it might be cooled, and this would lead to the discovery that water not only cooled but hardened the mass. In some such way the original smelter made his discovery, and came by the material that is now revolutionising the world.

That original simple process of smelting is still imitated, though with elaborations, in every country that has rich iron ores and forests close at hand; and the best iron, or roughly prepared steel, as in Sweden, is released from the ore on an unpretentious hearth, by means of a charcoal fire. Indeed, it was not till the beginning of the eighteenth century that coal, in the form of coke, instead of charcoal, was used successfully for smelting; and the story of the English iron industry before modern times is in great measure the story of the destruction of our forest lands.

The Little Bit of a Sussex Forest that Still Stands Round St. Paul's

The steel-producing areas were at one time the Wealden forest of Kent and Sussex, Rockingham Forest in Northamptonshire, the Forest of Dean in Gloucestershire, and the forest in Hallamshire, along the courses of the Rivelin, Rother, and Don, that surrounded the ancient town of Sheffield. The half-mile of iron railings round St. Paul's Cathedral are made of iron from a Sussex forest. Now only the Forest of Dean remains a forest; and though Sheffield is still the greatest steel-making centre in the world, its one reminiscence of the days of charcoal-made steel is its Bole

THE GLOW OF THE FURNACE BY NIGHT

PHOTOGRAPHS OF THE GREAT STEEL WORKS AT PITTSBURG TAKEN AT NIGHT

The facilities of some of the greatest and best-equipped iron works in Sheffield were placed at the disposal of Popular Science for the photographs in these pages, which were taken at the Park Gate Iron and Steel Works; the works of Messrs. Brown, Bayley & Co., Attercliffe; and the Toledo Works of Messrs. Andrews. The photographs of Pittsburg Steel Works are by Mr. Van der Weyde.

hills—that is bale, fire, or furnace hills—sloping up from the west, and in the olden times concentrating on the specially placed smelting-hearths an intensified natural draught. In his "Short Studies on Great Subjects," Froude pointed out that the county of Kerry, now apparently doomed to perpetual barrenness, was denuded of its supposedly inexhaustible forests to smelt imported ores. It has been argued seriously that the ultimate problem of industry will not be a scarcity of iron, but of fuel with which to melt it, so abundant is the metal in the earth's crust. The use of coke as a melting fuel began just in time to save a remnant of English woodlands.

Iron ore—the iron varying in richness from 20 to 70 per cent. of the whole—is found in all parts of the earth, but in some localities it is so mixed with elements harmful in steel-making as to be almost unusable. Sulphur and phosphorus are the most deleterious ingredients. The richest ores in continental Europe are deposited in Sweden, Styria, Luxemburg-Lorraine, and Spain; and in the British Islands in the Barrow district, Staffordshire, Lanarkshire, Cleveland, West Yorkshire, Lincolnshire, and Northamptonshire. But each of these deposits is comparatively insignificant compared with the quantities obtainable in the Lake Superior district of the United States and Canada. It is the use of this enormous store of raw material that has placed America far ahead in its aggregate production of steel, if low and high grades at small or large prices be included in the reckoning.

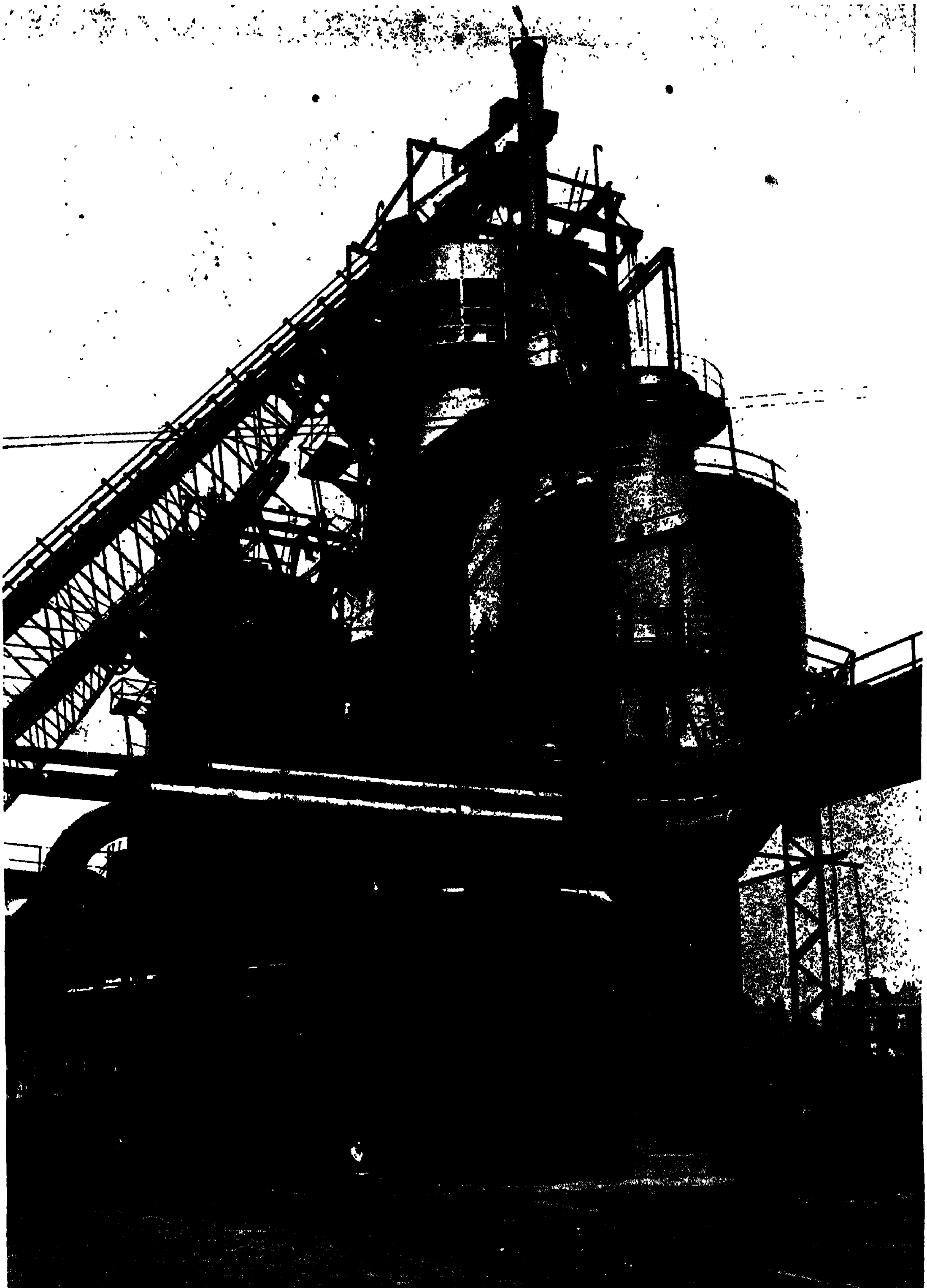
As brought from the earth in ore, unreleased and unrefined, iron groups into three types—magnetic, hæmatite, and carbonate ores. The magnetic ores, richest of all, are found in Sweden and the Lake Superior region; the hæmatites in the United States, Bilbao (Spain), Luxemburg-Lorraine (Germany), Cumberland, Lincolnshire, and Northamptonshire; and the carbonate ores in Styria, Staffordshire, Cleveland, South Wales, West Yorkshire, and Lanarkshire.

POURING IRON INTO TRUCKS WHICH CARRY IT TO THE TOP OF THE FURNACE

In the proportions of the elements that compose it an ore is usable for the production of iron castings, or of mild steel made for constructional purposes by the Bessemer process, or of high-grade steels of great monetary value made by the crucible process, and suited for operations of the finest nicety. The presence of sulphur or phosphorus in undue proportions makes an ore unworkable when melted, but manganese may give it an added value. The Barrow ores are comparatively free from phosphorus, though most English ores have an embarrassing proportion of it. The Styrian ores are exceptionally free from phosphorus, and have an unusual percentage of manganese. And Swedish ores, both by their quality and first rough processes of manufacture for transport, are competed for keenly by buyers coming from wheresoever good steel is made. The principal question involved in the productive processes to which we must now allude is that of quality, since the gradings of partly refined ore, and the steels prepared from them, cover a remarkable range of monetary values. Steels vary in their types and values as much as woods vary in their decline from a fine piece of mahogany down to a deal board.

The object of the first process is the extraction of the iron in a crude state from the stony or earthy ore in which it has been deposited, and this process varies in character and accessories according to national custom and the requirements of the different ores. When the percentage of iron to refuse runs low, large furnaces and great heat are needed—as with the Cleveland ores—but where the deposit is pure and rich, small furnaces and individual labour may suffice. The object in either case is to separate the iron from its attendant impurities. Usually the furnace is a hollow tower fed from the top with ore, fuel, and lime—the lime being added so that under the action of heat it may coalesce with the silicates in the ore. A powerful blast of hot air is introduced at the bottom till the

THE OUTSIDE OF THE BLAST FURNACE



This photograph gives an impression of the almost incredible strength of the furnaces in which the hottest fires that men can make are always burning. The truck of iron ore, seen being filled in the previous picture, is here being poured into the shaft. What happens inside the shaft is seen in the next picture.

whole mass of metal is liquefied, while the lime and silicon form into a cinder or slag, which floats on the molten iron and allows it to be drawn off below and run as a stream of fire into channels of sand, where it cools and sets. This is pig-iron, the raw material than iron and carbon, such as silicon, phosphorus, sulphur, copper, and manganese. A large amount of carbon makes it hard, brittle, and unworkable by the hammer, though if of good quality it may be used for rough castings.

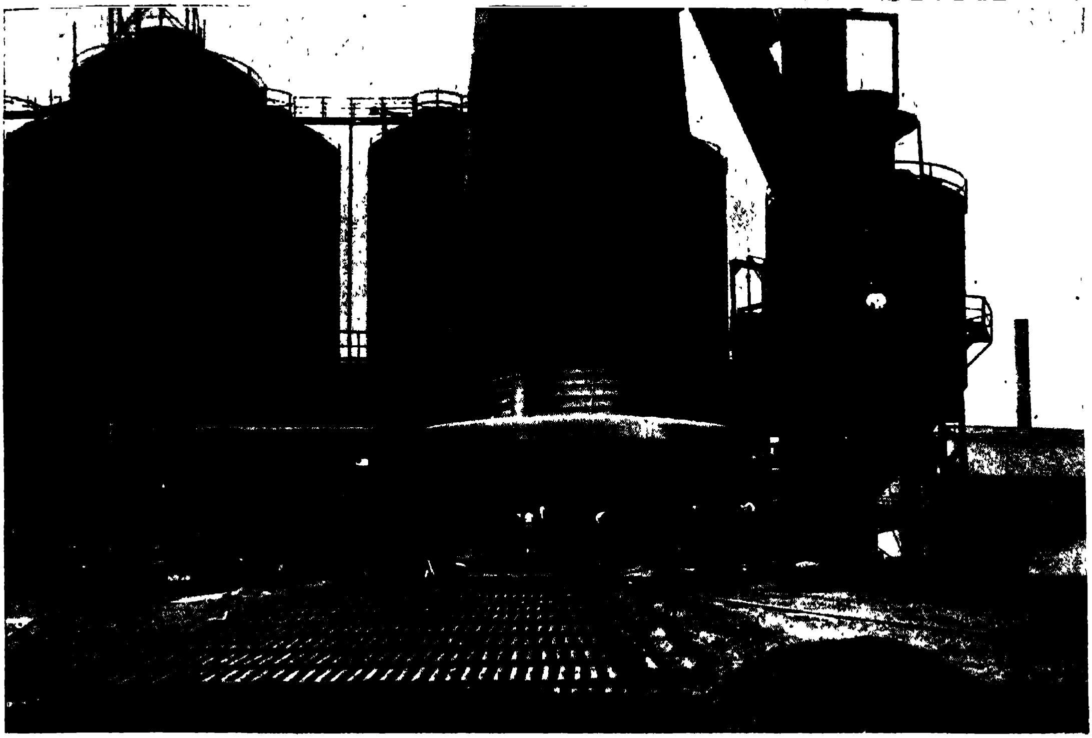
INSIDE THE GREAT BLAST FURNACE—THE FIRE FROM WHICH IRON RUNS LIKE WATER

This section of a furnace shows how the lid is lowered so that the iron ore falls into the fire. The lid closes, and gases rush into the pipe on the right and into the stove, where they help to work the machinery which drives the hot air into the bottom of the furnace. It is the tremendous force of this blast of hot air, rushing through the fiery furnace, that melts the iron until it trickles out like water.

of the steel industry. Pig-iron is graded according to the different conditions of the carbon it has taken up from the fuel with which it was melted, but it contains a varying percentage of other ingredients

The next step is to make it more adaptable, more easily manipulated, and so increase the range of its uses. To this end it is melted again, and while in a molten state is "puddled" in the furnace, being stirred

AT THE FOOT OF THE GREAT SHAFTS



A NEAR VIEW OF THE SAND MOULDS IN WHICH THE IRON SETS

A CLOSE VIEW OF THE BLAST FURNACE AND THE AIRSHAFTS FROM WHICH THE HOT AIR COMES

The iron runs out of a furnace into moulds cut out in sand, where it sets in solid bars or ingots. The sand moulds, shown at the top of this page, are shown filled with white-hot iron on the previous page.

and worked and squeezed with a long iron bar to release the iron from more of its impurities and reduce its carbon. When the iron so treated has also been hammered and rolled it is called wrought iron, and is soft enough to be heated and worked by hand into any shape.

But wrought iron and mild steel are really indistinguishable by their chemical contents. Wrought iron is iron with less than ·3 per cent. of carbon in it. With from ·3 per cent. to 2·2 per cent. of carbon the composition is commercially known as steel; and with from 2·2 to 4 per cent. of carbon the substance is cast iron—hard, brittle, and unmalleable. Steel, indeed, has been defined as carbonised iron, intermediate between wrought and cast iron; but, as a matter of fact, steels are formed with as little carbon in their composition as wrought iron has, and with as much as cast iron has.

The aim in making steel is to control the composition of the substance anywhere between the extremes of softness and hardness, so as to suit whatever purpose may be in the mind of the manufacturer; and by using alloys a greater hardness than cast steel may be produced without any toughness being lost. In short, the skilful steelmaker scientifically takes command of the composition of his product. This is essential if great responsibility has to be placed on the material when it comes into use. But, short of that, large masses of lower-grade steels are made for more general purposes by cheaper methods; and we must look for a moment at these popular productions, for steel has conquered along two main lines of advance—one the line of quantity and cheapness, and the other the line of quality and supreme fitness.

CATCHING THE SLAG, OR DROSS, OF IRON ORE AS IT RUNS FROM THE FURNACE

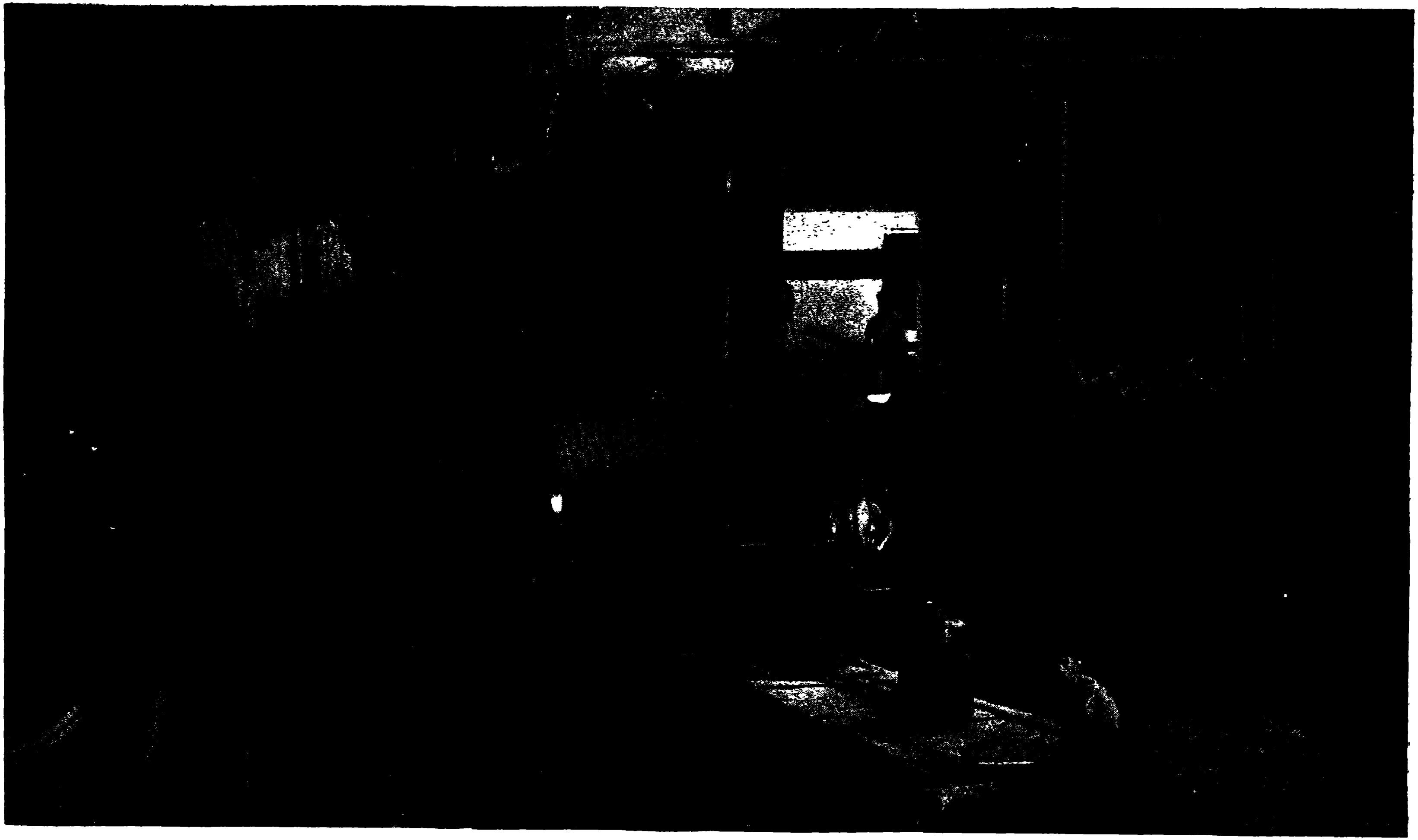
Until the middle of the eighteenth century steel was of irregular and doubtful quality, the reasons for its variations being ill understood. But in 1740 Benjamin Huntsman, an ingenious clockmaker from Doncaster, settled on the outskirts of Sheffield, and secretly began making steel of a superior character by breaking up carefully selected steel into small pieces, and remelting it in small clay crucibles — hence the name "crucible cast steel." Huntsman's plan was discovered eventually by his Sheffield neighbours and widely imitated, and the district acquired a reputation for producing the finer qualities of steel.

Henry Bessemer, the inventor who revolutionised modern steel-making by enabling the commodity to be produced in large

A RUNNING STREAM OF WHITE-HOT IRON

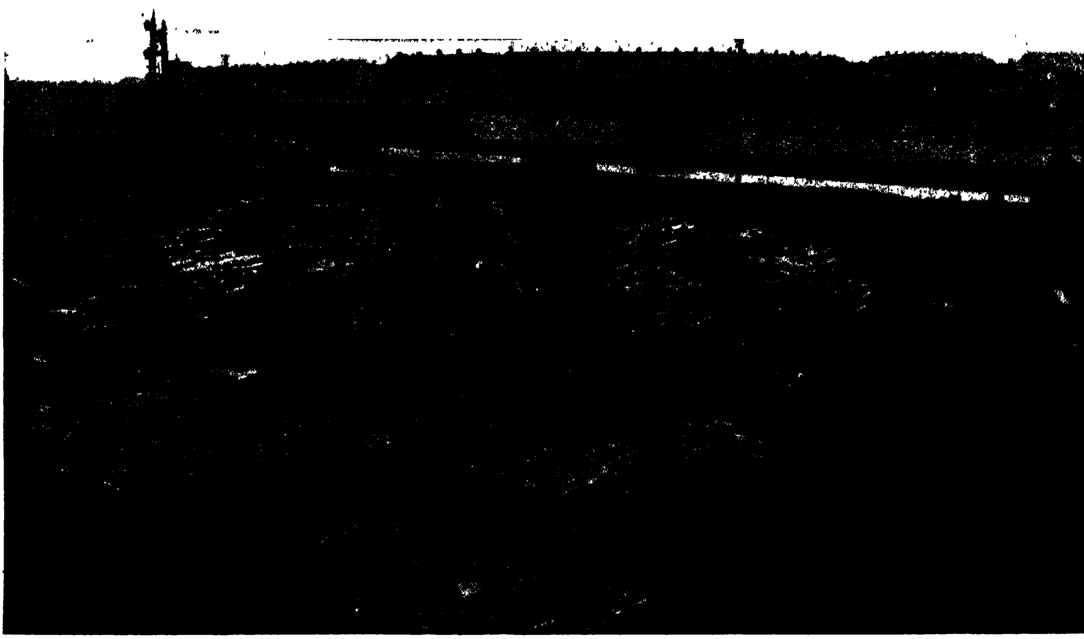
The top picture shows iron at white heat running through the mould in the ground. The lower picture shows an enormous ladle pouring out thirty tons of molten iron brought direct from the blast shaft, and now being poured into a furnace for conversion into steel.

A STREAM OF IRON FROM THE FURNACE RUNNING INTO THE CONVERTER TO BE MADE INTO STEEL



The molten metal that runs from the furnace is called pig-iron—so named because the moulds into which it runs were said to look like little pigs; and the pig-iron that is to be made into steel is directed, either direct or in ingot form, into a Bessemer converter, where other chemical substances are introduced. A terrific blast of cold air is blown through the converter through small jets, and the next picture of the converter shows this huge vessel in full blast.

quantities at a cheap rate, was also associated with Sheffield, where he set up his works. He was the son of a naturalised Frenchman. His plan was to blow through molten pig-iron a cold blast of such intensity as to burn out most of the carbon, and leave a mild steel suitable for rails, wheels of railway carriages, boiler-plates, and shipbuilding. His steel was almost as workable as wrought iron, though liable to brittleness on account of the continued presence of phosphorus. Bessemer sought to avoid the difficulty of eliminating phosphorus by selecting for his experiments and manufacturing operations Swedish and Cumberland ores poor in phosphorus, and he so far



IRON ORE ON THE MIDLAND RAILWAY AT SHEFFIELD WAITING TO BE TAKEN TO THE FURNACES

succeeded that the use of steel in bulk became not only a possibility but an economy in many directions. Before his time steel had been used for little except making cutlery, tools, and springs. Bessemer received more than a million pounds in patent fees, and his process, with modifications, has been adopted throughout the world.

Later, by lining the Bessemer furnace, or converter, with lime, Sidney Thomas and Percy Gilchrist got rid of a large proportion of the phosphorus left by the Bessemer process, and so reduced the brittleness of the steel. Their method also brought into use lower-grade irons previously unremunerative. Incidentally, too, the combination of the phosphates and lime in the Thomas-Gilchrist process forms a valuable manure.

The story of the acceptance of Bessemer steel for the manufacturing purposes that it suited is a saddening proof of the almost desperate conservatism of men who pride themselves on being practical and despising theory. All the railways were using iron rails, that speedily flattened out and had to be renewed frequently. Steel rails were among the earliest manufactures on the Bessemer system. They were much dearer than iron rails, but then they would last ten times as long. But the engineers of the various railway companies would not admit that a steel rail could be workable. They rehashed the original argument against railways, and said the wheels would not bite on a steel rail. At last the Sheffield firm of John Brown & Co., which had adopted the Bessemer process and started the manufacture of steel rails, and had sidings of its own joining the Midland Railway, with the connivance of some of the company's platelayers continued their siding rails into the Midland main line, and substituted steel rails for iron. The demonstration remained undiscovered until the superiority of the steel rails was beyond denial. The admission of what had been done was then made to

the engineer of the line, who was asked to come and see. He saw, was convinced, forgave the subterfuge, and ordered the first consignment of the rail which by reluctantly allowed merit has become the rail of the world.

An alternative method to the Bessemer process is known as the Siemens-Martin process, in which pig-iron of a good quality is melted, and to it is added wrought iron and used Bessemer rails, with a combination of manganese and carbon.

The Cutting and Heating and Hammering of the Steel that Comes on to the Table

Manipulated material largely freed from its impurities is thus utilised and reinforced, and its quality is tested by ladling samples of the molten metal, the constituents of which can be judged with reasonable correctness and a homogeneous steel be secured.

The advances in the making of steel of the finest quality for special purposes have been as conspicuous as those by which large quantities of the cheaper material are produced.

The Sheffield cutler has a traditional belief in what he calls "double-shear" steel, a belief that borders on affection. Bars of rough steel, or "blister" steel, in which the iron and carbon are but irregularly and not homogeneously united through the whole mass, are broken up again into shorter lengths and formed into a bundle, or faggot; then reheated and hammered under a heavy mechanical hammer. The process is repeated, and the steel so treated is called "single shear" or "double shear," according to the number of cuttings, heatings, and hammerings through which it has passed. Steel worked in this way is far superior to that produced by the Bessemer process, especially for cutlery.

The Marvellous Steel that will Cut for Hours with its Edge White-Hot

The latest sensational developments in the steel world have been seen in the perfecting of crucible steels of the highest quality, particularly the "high speed" variety. These steels are made largely with alloys, manganese, tungsten, chromium, and nickel being used in conjunction with iron, and, of course, carbon. The best Swedish bar-iron, whose composition can be estimated, is melted in a clay crucible, and to the molten mass are added alloys in their purest form, so that the composition of the liquid may be scientifically adjusted, and the proportions of iron and carbon with the alloys may be controlled. In this way special steels are prepared, their exact properties being understood, and their adaptation to particular uses secured. Thus "high speed" steels are made which in the form of a drill will cut other steels with an apparent ease that suggests a tasting-scoop boring its way through a ripe cheese; and when a turning tool becomes white-hot in machining a shaft running at an almost incredible speed, it will keep its cutting edge unaffected for hours. So valuable are some of these special steels that they sell at as high a price as £250 per ton, whereas thoroughly good tool steel for ordinary purposes may be bought for £50 per ton, and satisfactory Bessemer or Siemens-Martin steel for £10 per ton.

Steel is not only made harder on the one hand, or more workable and ductile on the other hand, by its carbon contents, but also by hardening and tempering, and the manner in which it is cooled. It is hardened by sudden cooling and softened by slow cooling. The change of temperature is told by changes of colour, and the steel can be raised or let down in temper according to the use to which it is to be put.

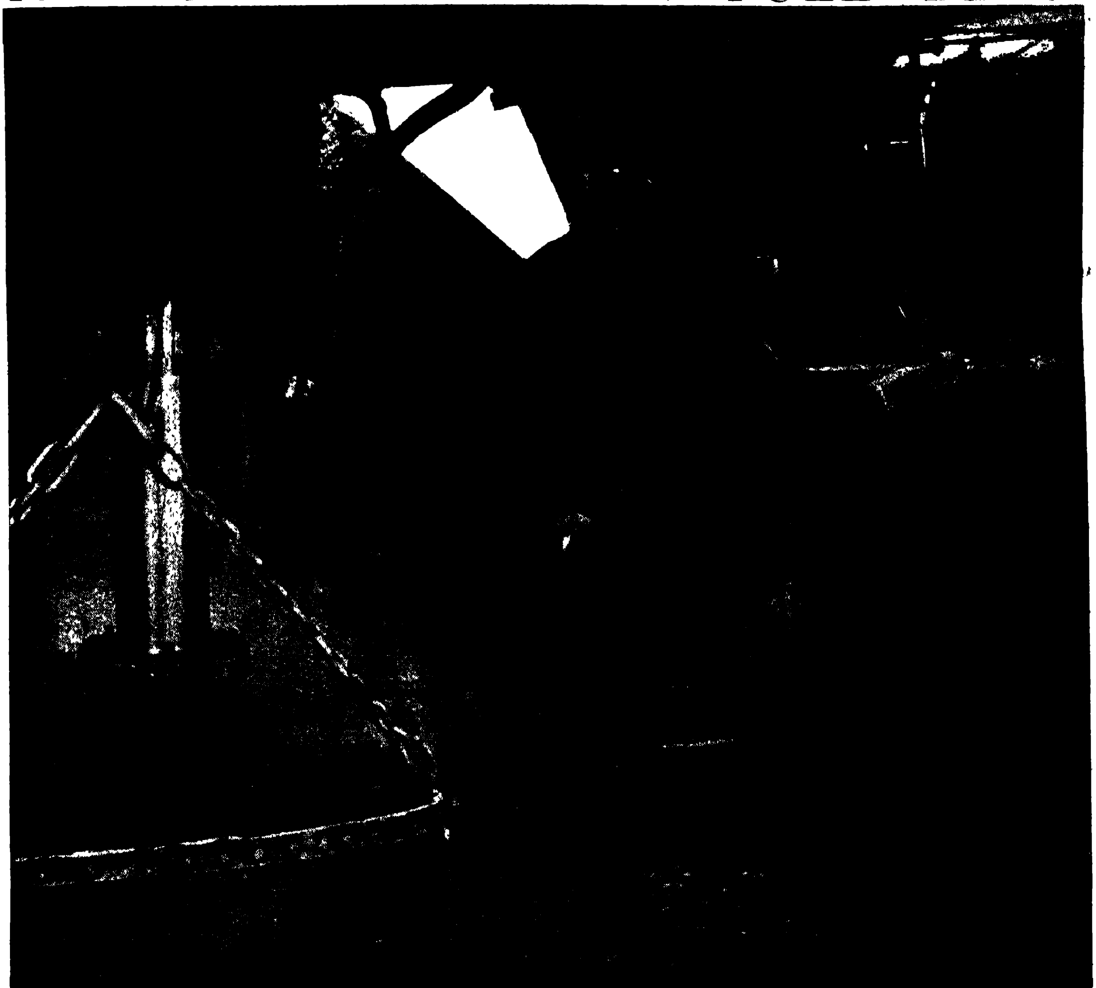
The Material that Goes Out from Sheffield to Help on the Work of all Nations

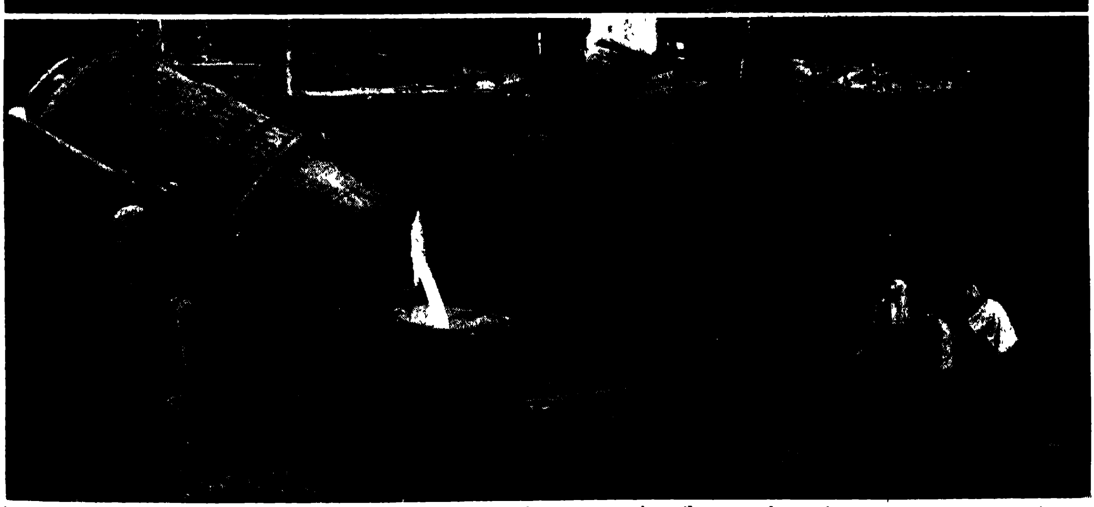
Some alloy-steels have the remarkable property of combining strength and hardness with ductility, and are made ductile by sudden cooling, so contrary and elusive are the qualities of this Protean substance, the secrets of whose manufacture are guarded with jealous care by the staff of metallurgical chemists who control in the great works the production of the wonder-working metal.

While enormous quantities of low-grade steel for general trade purposes are produced in the United States and Germany, and similar qualities are also made in various parts of Great Britain, the highest qualities of steel, of great value compared with weight, are almost exclusively made in Sheffield; and American, German, and French manufacturers buy largely from the Yorkshire city the steel they need for the more delicate and responsible parts of the machinery they are making.

All the world has heard of Sheffield as a cutlery centre; and it is widely understood that the city is busy forging great guns and armour plate, and making shells, through such firms as Vickers', Cammell's, Brown's, and Hadfield's, but it is not equally well known that the city, through its Clyde, Continental, Toledo, Dannemora, Brightside, and Portobello steel-making plants—

THE STEEL-MAKER IN FULL BLAST





Out of the middle of the Bessemer converter rushes a roaring flame—first violet, then orange, then dazzling white, and at last a faint blue, which is the sign that all the elements except the iron have been burnt up. The unknown quantities of chemical substances are now removed, and *known quantities* are poured in, the effect of which, when the full blast of cold air is turned on, is to change the white-hot mass of iron into steel. The lower converter is pouring out twenty tons of finest steel.

to name only half a dozen works out of scores—is supplying as a raw material steel of the rarest quality to the manufacturers of all nations.

Only one hundred and fifty years ago steel was used merely for the construction of a few common vessels of the domestic type, and for whatever tool, instrument, or weapon needed a cutting edge or thrusting point; yet now it has become the supreme substance in all processes of industry that require machinery, or a strength and stability short of massive weight. Capable

STEEL, FRESH FROM THE CONVERTER, BEING POURED INTO MOULDS

of being forged by hammering or rolling, or of being cast to almost any shape in a mould, of being bent without losing its tenacity, of being cut and welded, of being drilled and riveted by the use of itself when properly composed and tempered for the purpose, steel has taken command of all other constructive materials, such as wood and stone, and has deposed them into quite a secondary place, so that they become little more than accessories to its pervasive strength and adaptability.

In the ancient industry of agriculture, as carried on up to date, steel has dispossessed three-fourths of the labour of man, and half excluded the horse. From the starting point of the bright ploughshare, which not long ago was the only hold that steel had on agriculture, it has annexed the sowing of the seed, the clearing of the weedy ground, the reaping, binding, and gathering of the grain, the thrashing of it, and its conveyance by traction engine to the station. It sinks the farmer's well on his farm and carries water for him to convenient drinking corners. It wire-fences his fields, and gives him the shelter of galvanised sheds. Almost the only one of its older uses left is the lining of his cart-wheels with iron, unless, indeed, the modest sickle, scythe, and spade be used on the smaller plots, or in out of the way districts. The waste products from its purification come to the farmer as manures.

In the one human activity that is older even than farming—that of fighting—steel has taken such a leading part that the only

STEEL FROM A SIEMENS-MARTIN FURNACE FLOWING INTO THE HUGE LADLE

THE TONS OF STEEL SHOWN ABOVE BEING POURED INTO MOULDS

competitor challenging comparison is the allied science of explosives. The monstrous warship is but a steel smithy. Whatever wood she may have is so small a part of the whole that in a battle it may burn away unheeded. The sides of the monster are steel hardened to the last degree, with such skill that if they be pierced they will not crack. The projectiles flung from the great guns are steel-bodied and even more formidably steel-nosed, so as to pierce the densest and thickest armour if the blow can be squarely struck. All that both arms and armour were to the knight of old, steel is to the armies and navies of to-day.

The Amazing Metal which has every Factory in the World at its Mercy

In the manufacturing world every industry, including those that depend on animal and vegetable life for materials—on wool, and silk, and leather, on cotton, rubber, and fibre—is at the mercy of steel, through the machinery that prepares all materials for human use. The factories of Manchester, Leeds, Nottingham and Leicester are crammed with machines that have their origin in the ores of Sweden, Barrow, Cleveland, and Staffordshire.

The building and equipment of our houses, offices, and shops mark one of the highest advances of the tidal wave of steel. Almost every modern urban building that has pretensions to stability of construction and rapidity in erection has its walls now filled in on a framework of steel. It is this domestic use more than anything else that has contributed to the enormous growth of the low-grade American steel trade. Except where wood, stone, or brick-clay are ready to men's hands, steel and cement seem likely to become the building materials of the civilised world.

How Steel Keeps Company with Most of Us Throughout our Daily Lives

Note how, from the domestic point of view, steel enters into the morning life of the average citizen. He is awakened to consult a watch whose life-force is a spring of the best-tempered Sheffield steel. He rises from an iron bed, made easy by steel springs. He shaves with a Sheffield razor, though the Hamburg grinder of it may have given it a German name. If the house is of modern build, the occupier may descend by a steel staircase, to eat with steel cutlery a breakfast cooked in a cast-iron oven with steel fittings. He takes his confidential papers for the day's use out of an impregnable steel safe; makes notes of his morning's correspondence with a steel pen; and, his watchful wife having made safe an unsteady button by the help of a steel needle, he leaves the house, pausing for a pleasant moment to hear his child practising music on a piano strung into perfect pitch by the finest steel wires.

Turn to the modern industry of mining, and we find that steel has taken a place of prime importance. The lives of the men who descend the coal mine are suspended from a thin rope of twisted steel wires. Whatever machines or tools are used in releasing from the earth its minerals, and its metal ores, in whatever type of mine, worked by steam, or electric power, or by hand, they are made of specially tempered steel; steel ropes, too, are the universal instruments of haulage. It is the endless steel wire that smoothly slices the slab of marble from the face of the quarry where it has been deposited. It is the steel stamper that pounds the gold-bearing rocks to powder, the bell-shaped crusher that breaks down into smaller and smaller pieces whatever rocks are drawn into its irresistible maw. Other materials are conquered by steel as if in play. The keen steel axe fells the giant tree, and the steel saw shapes its huge bulk into beams, planks, shingles, and innumerable shapes for the joiner's use.

The King of Metals that carries Man and Materials to the Ends of the Earth

Most of all, however, the reign of steel as the king of metals is proved by the part it takes in the transport of man and materials to the ends of the earth by land and by sea. The tramways in our streets might be used to illustrate the qualities of almost every kind of steel, from the rails of ordinary strength, to the special lengths in sharp curves, points, and crossings, hardened to endure any degree of grinding action from the car wheels, while the heavy machinery under the floor that steadies the lofty car tells a new tale of the use of steel in electrical generation and appliances. The tube railway burrowing through the earth is all steel, with the trains it carries and the lifts that feed and relieve it, except a few trifling wood and glass fittings. It is much the same with the railways—the great engines that career along them, the tracks over which they run, the carriages that give us comfort—framework, axles, wheels, tough couplings, springs that sway us with the smoothness of aerial motion—all are of steel; and so, too, are the mighty bridges that straighten the pathway over mountain gullies and span the broad-mouthed rivers.

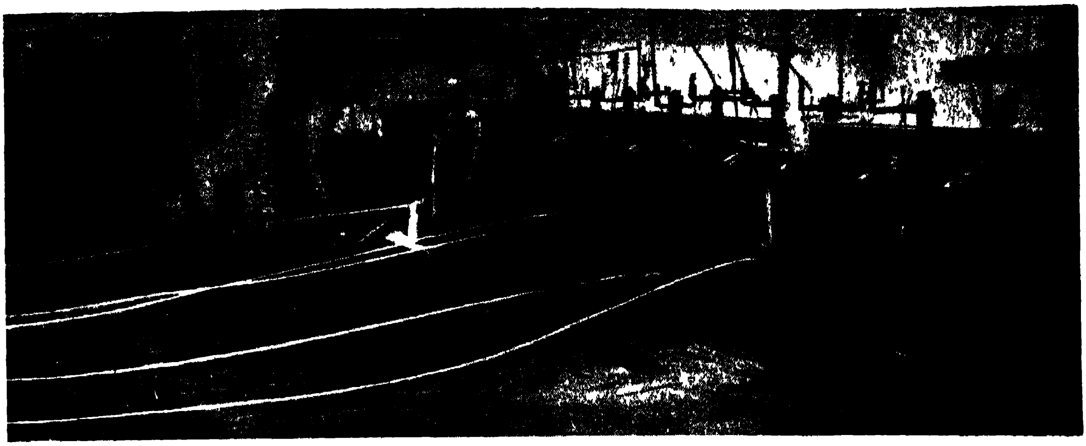
competit
allied scie
warship
wood she
whole th
unheede
steel ha
such ski
not crac
great gu
formida
densest
be squa
and arr
steel is

The A

In t
industr
animal
on woo
rubber,
throug
materi
of Ma
Leicest
have t
Barrow
The
houses
highest
Almost
has pr
and ra
filled
this d
that
growt
trade.
clay
cemen
mater

Ho

Not
view,
the a
consu
of th
rises
sprin
thou
have
hous
desce
steel
iron
confi
an in
his r



A TREMBLING BAND OF IRON—AN INGOT BEING ROLLED INTO A RED-HOT RIBBON

The steel, having been set, is put under an enormous steel hammer to be flattened, hardened, and shaped for standard weights. Some must be rolled out into long, thin lengths, as in this photo, showing a band of red-hot iron running to and fro through a series of rollers.

If we choose to be our own propelling force, the friendly bicycle is entirely made of steel, tempered to suit the particular use of each part, the ease of its working being dependent on the adoption of one of the finest steels for ball-bearings. The motor-car is an elaborate triumph of steel construction, only equalled, perhaps, by the latest development of man's ingenuity, the flying machine, in which the safety of the aviator depends not less on the quality of his tense steel stays and unfracturable machinery than on his own skill as a helmsman or the caprice of the winds.

But most of these illustrations of the potency of steel as the world's prime material in strength and manageability grow feeble in comparison with the great steel ship, ploughing through the ocean storm, with her thousands of souls aboard, steel in all essential parts, with wood and glass and felt appearing only in the ornaments and dressings. The huge beams, bulkheads and keel on which her sides are clamped are steel; so also the doors that shut her into watertight boxes; the sides that sink deep into the sea and tower high above it, are steel in every plate and rivet; steel the great labouring engines and the huge propeller-shafts that thrust her headlong quivering through the waves; steel the boilers that generate and store her power; steel the masts that are her reserve resource, and the very rigging that takes the place of the ropes of an older industrial world; steel, too, the hawser that holds her steady at her anchorage; while, should accident happen, it is on the expert craftsman in steel engineering, with his tools and stores aboard, that the passengers must rely for repairs and safety.

FIVE TONS OF WHITE HEAT

A five-ton ingot of steel, white-hot from the furnace, on its way to be rolled into armour plate.

The chief activities of the civilised world have been revolutionised during the last fifty years—a revolution of progressive intensity, depending, on its material side, upon the utility of steel. Behind this progress, no doubt, has been the discovery of methods of generating mechanical energy, but the practical use of this energy, however generated, has depended upon the development of a constructive material strong enough to convey or even store the energy, and that material is steel, which has responded to all the demands made upon it, and has enabled the inventive genius of mankind to secure an expansive and complete expression.

A FLAME THAT ROARED LIKE THUNDER

THE TREMENDOUS POWER OF NATURAL GAS—A FLAME, KINDLED BY LIGHTNING, WHICH ROARED LIKE THUNDER AND BURNED 200 FEET HIGH FOR FIVE WEEKS, IN KANSAS

THE WORLD'S REAL WEALTH

The Millions of New People Coming into the World and the Effect on World-development

USING UP THE ENERGY OF THE FUTURE

LITERATURE abounds with terms in which the world is expressed as huge, enormous, but the astronomical student quickly finds cause to revise his early conceptions of the greatness of the planet which is his moving observatory.

He learns that the earth is small, even as compared with some of the other bodies bound by gravitation to the Sun, and that the Sun, which dwarfs the earth to comparative insignificance, is himself a star of no great order. But it is not only in relation to the cosmos that the earth has exceedingly narrow limitations. It is of the utmost importance for the student of commerce to realise that the planet we live on is small even in relation to man himself and to the needs of man. It is not necessary to use the earth's orbit as a measuring line to realise how man is "cabin'd, cribb'd, confin'd" within borders by no means too great for his needs and aspirations.

We are not concerned here with the possibilities or probabilities of the remote future, and the prophecies of Professor Lowell as to mankind perishing on a waterless planet need not detain us. Considering merely the near future, however, in the sense of the next few generations, it is of profound importance to observe that the rapid increase in the number of men, combined with the rapid increase in the standard of life of nearly all men, makes a general survey of the earth's resources incumbent upon us if by industry and commerce we are to furnish forth in amplitude the material framework of civilisation, and supplies to maintain thousands of millions of highly developed human beings.

It is difficult to estimate even approximately the rate of increase in the world's population as a whole, but the increase of the great white civilisations alone is over six millions a year. Comparing the figures for 1831 and 1896 with those of 1909, for Europe, the United States, and the British Colonies, we find a remarkable advance.

The facts present abundant food for reflection to all who are interested in the development of mankind. Here are these wonderful and significant figures. They cover the greater part of Christendom, the Latin American Republics being the most important omissions from the table.

RISE OF POPULATION IN GREAT COUNTRIES

The figures are given in round millions

Country	1831	1896	1909
United Kingdom	24	40	45
France	33	38	39
Germany .. .	29	52	64
Russia	55	106	120
Austria	30	43	50
Italy	21	31	34
Other countries .	36	59	67
Total for Europe	228	369	419
United States .. .	10	70	89
British Dominions .	2	12	19
Grand total	240	451	527

In Europe, the British Dominions beyond the seas, and the United States, the population has much more than doubled in about three-fourths of a century. The European population has almost doubled, in spite of the great tide of emigration to the New World, which has swollen the populations of America and the British Dominions. The extraordinary growth and development of these parts of the world stand out as the chief feature of the record. We may note the almost stationary character of the population of France, which in 1831 possessed one-third more people than the United Kingdom, but now is less than Britain by over 5,000,000. The advance of Germany is also notable, and is an expression of what industry and

commerce can do for a gifted people when associated with peace and security. It is impossible to furnish satisfactory comparative figures for Latin America, but here also great advance has been made in recent years, Latin America now numbering a population of about 60,000,000 people. In 1911 the population of the whole of the American continent reached about 160,000,000, against about 430,000,000 in Europe. In an incredibly short space of time—little more than two generations—the American continent has become a congeries of great States possessing a total population almost as great as that possessed by all Europe two generations ago. The United States alone has nearly a hundred million people.

Simultaneously the great and unnumbered populations of Asia and Africa have been making vast increases. The energetic inhabitants of Japan are reaching out to the continental mainland. Australasia, it is true, has still but about five millions of people in the vast spaces of this great continent, but immigration is increasing, and the twentieth century will undoubtedly add enormously to the population.

The Potentiality of a Great Nation that Comes New into the World Every Year

The birth-rate of the white peoples has been falling, but their death-rate has been also reduced; and with the progress of preventive medicine we may expect a further improvement, especially in infantile mortality. There is every reason to believe, therefore, that the near future will witness the continued multiplication of mankind. The importance of a proper distribution of the world's production will consequently increase, and the leaders of men will be driven by necessity to greater efficiency in the production and distribution of food and other commodities. The world's population is approximately 1,600,000,000, and it is probably increasing at the rate of about 20,000,000 a year. We have to endeavour to realise that the world's resources are drawn upon each year by an additional mass of people as great as about one-half the population of the British Isles. The earth gains in twelve months enough new people to make a new great nation.

Man has already explored and mapped nearly the whole of the land surface of the earth, which occupies about one-fourth only of the world's area. The land surface of the earth is about 53,000,000 square miles; and it is of interest for the British reader to note in passing that the British Empire covers about 11,300,000 square miles, or more than one-fifth of all the world's land, containing about one-fourth of all the world's people.

The distribution of land upon the earth's surface presents some remarkable features. By far the greater part of the land lies north of the equator. The great continental masses taper to the south. A hemisphere with the British Isles as its centre contains most of the land of the world; a hemisphere with New Zealand as its centre is nearly all water surface.

The Half of the World in which the Greater Part of its Work is Done

It is in the North Temperate Zone that the greater part of the world s work is done. Here live the majority of the world's white people. In the South Temperate Zone there is comparatively little land, and here are to be found the million whites, Briton and Boer, of South Africa, the 5,000,000 whites of Australasia, and part of Latin America. In the Torrid Zone is the greater part of the African continent, the Indies, and a large part of South America.

The researches of recent years open up great possibilities with regard to the colonisation of the tropics. We have come to realise, through the labours of Sir Ronald Ross and others, that insects are the conveyors of such dread diseases as yellow fever, malaria, and sleeping sickness, and that if the white man can successfully wage war on the mosquitoes and other flies which introduce the bacteria of these diseases into his blood by their stings he can live and work in tropical countries. The point has been put to the test on a very large scale, by American Government enterprise, at the Isthmus of Panama.

The Hope that Science will open the Gates of the Tropics to Commerce and Civilisation

In the days when French companies were at work on the Canal, construction proceeded slowly and at enormous cost of life. Parties of vigorous young Frenchmen went out to Panama, to perish or to become permanent invalids. The American Government began by preventing the breeding, on the Canal zone which they purchased from the Panama Republic, of the two varieties of mosquitoes which respectively convey malaria and yellow fever. As a consequence, these dread diseases have been entirely banished from the Canal works. The death-rate of all employees of the Canal work in 1909-10 was only 10·84 per 1,000; and the American chief sanitary officer, Colonel W. C. Gorgas, gives it as his opinion that it has been conclusively

CAN SCIENCE COLONISE THE TROPICS?

The colonisation of the tropics by white men is one of the vast potentialities of science and commerce. For generations the two mosquitoes which carry the germs of malaria and yellow fever have held Panama in their grip, as our artist has suggested here, but at last science is protecting people from these diseases, which have entirely disappeared from the Panama Canal works. Science, in other words, is opening the gates of the tropics once more to wealth, civilisation, and population.

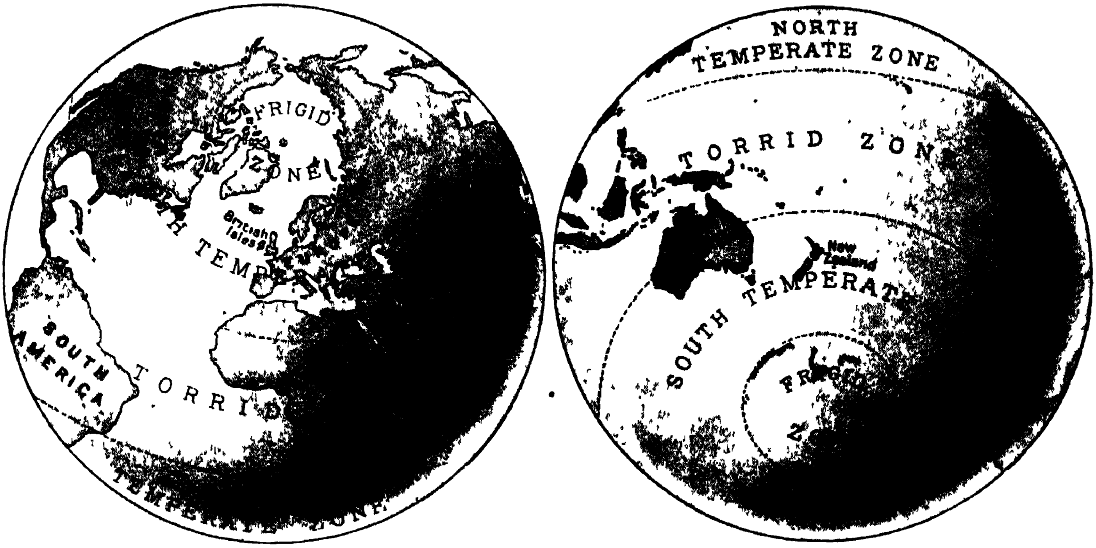
BIND TO FACE PAGE 233

proved that white men can colonise the tropics, the Torrid Zone. He says: "I think the sanatorium can now show that any population coming into the tropics can protect itself against these two diseases—malaria and yellow fever—by measures which are both simple and inexpensive; that, with these two diseases eliminated, life in the tropics for the Anglo-Saxon will be more healthful than the temperate zones; that gradually, within the next two or three centuries, tropical countries, which offer a much greater return for labour than do the temperate zones, will be settled up by the white races; and that again the centres of wealth, civilisation, and population will be in the tropics, as they were in the dawn of man's history, rather than in the temperate zone, as at present."

When we remember that at the tropics the fruitful earth gives a succession of crops throughout the year, and that many most valuable natural products can only be raised in a tropical climate, we understand how much the scientific conquest of the equatorial regions may mean to the future of mankind. At present, however, such developments are little more than in embryo, and the industrial and commercial leadership of the world is centred in the North.

Consideration of the important figures on page 231 will show what enormous changes in the character and direction of the world's commerce have been caused by the redistribution of a great part of the world's most gifted races. This redistribution is not only continuing, but accelerating; and the twentieth century will witness changes even more remarkable than those revealed by our survey of the development of Christendom in the last eighty years.

The Governments of "new" countries are beginning actively to advertise their attractions and resources to the peoples of the Old World, in order to gain citizens and capital. This is true not only of the great British dominions, but lately of the South American Republics. New lands will gain increasingly by immigration, and by the export of capital from settled countries, as well as by their own native increase, and as a consequence commerce will greatly change in volume and in nature as between various parts of the world.



THE TWO HALVES OF THE WORLD, SHOWING WHERE MOST OF THE WORK OF THE WORLD IS DONE

A hemisphere with the British Isles as its centre—the North Temperate Zone contains most of the land of the world; a hemisphere with New Zealand as its centre—the South Temperate Zone—is nearly all water surface. It is in the countries within the North Temperate Zone that most of the white people live and most of the work of the world is done.

What are the great economic forces which determine these changes in the distribution of population and of the world's industry and commerce? The answer to this question is a key to the proper understanding of the world's activities, and of the greatness of certain nations.

The first and most important factor is the distribution on the world's land surface of considerable supplies of energy stored by Nature in a form available to man.

So far we have learned to obtain supplies of power on a large scale in only two ways—by the combustion of fuel and by the harnessing of water power.

Other sources of power are, of course, known to science, from the wind to radium, but none of them is of practical importance. It may be remarked in passing, however,

that the extraordinary and almost miraculous emanations of energy exhibited by radium—fully considered elsewhere in this work—may lead to a complete revolution of our conceptions of power-getting, and so alter the face of the world and the life of man as to render all that is written here obsolete and valueless. Dealing here with the world as we know it, and with scientific attainment as it is, we are compelled to recognise the all-importance of the distribution of the world's great stores of fuel, and of the world's great sources of water power, bearing in mind that these factors determine the distribution of industries, and therefore the centres of population, and therefore the direction and nature of commerce.

The Distribution of the Chief Fuels in Use Throughout the World

Let us consider, first, the distribution of the world's fuel.

Fuel is known in a number of forms, as wood, as peat, as coal or lignite, as oil, as gas, or as alcohol, and each of these forms has been utilised in practice for industrial purposes. Let us pass them in review.

Wood can be indefinitely increased by man, but the passing of wood as industrial fuel will be understood when it is remarked that the iron work of the United Kingdom, if now accomplished by wood fuel, would call for more timber than could be grown on the entire area of the British Isles.

Peat fuel is of considerable value, but the supply does not make it of considerable importance as an industrial factor.

Coal in its various forms exists in enormous quantities in various parts of the world. It is invaluable, and at present indispensable and unrivalled, as a readily available source of energy. Lignite, or brown coal, only less valuable than coal itself, has also a wide distribution.

Petroleum is in many respects more useful even than coal, but the world's supplies are comparatively not very great, and, as to their bulk, confined to a few countries, notably the United States and Russia.

The Coal that Determines the Industrial Leadership of the World

Natural gas is another fuel of great value, but the supplies are comparatively insignificant. The immense force of this gas when found in great abundance is seen in the picture on page 230. The natural gas which caught fire as shown in this picture had a force practically uncontrollable, so that the fire lasted five weeks, having discharged gas during that time at the rate of almost three-quarters of a million cubic feet a day. We may almost ignore the commercial value of natural gas, however.

Alcohol is an excellent fuel, which can be produced from organic sources, such as the potato, in practically unlimited quantities, but it is not an economic rival of coal or of oil in places where those fuels are found in quantities.

Coal thus stands out as the supreme fuel, and therefore as the arbiter of the distribution of industry depending on fuel. But, while the world's coal is enormous in quantity, its distribution is most unequal. The chief coal areas are situate in North America, in China, in India, in Australia, in Russia, in the United Kingdom, and in Germany. Coal area, however, is a very different thing from accessible coal—that is, coal at not more than half a mile, or at most 4000 feet deep. In coal thus available, the United States, the United Kingdom, Germany, and China appear to be the best now known; and the three former countries are consequently the leaders of the world of industry and commerce, though in the time to come an awakened China may possibly rank with them as a great coal power.

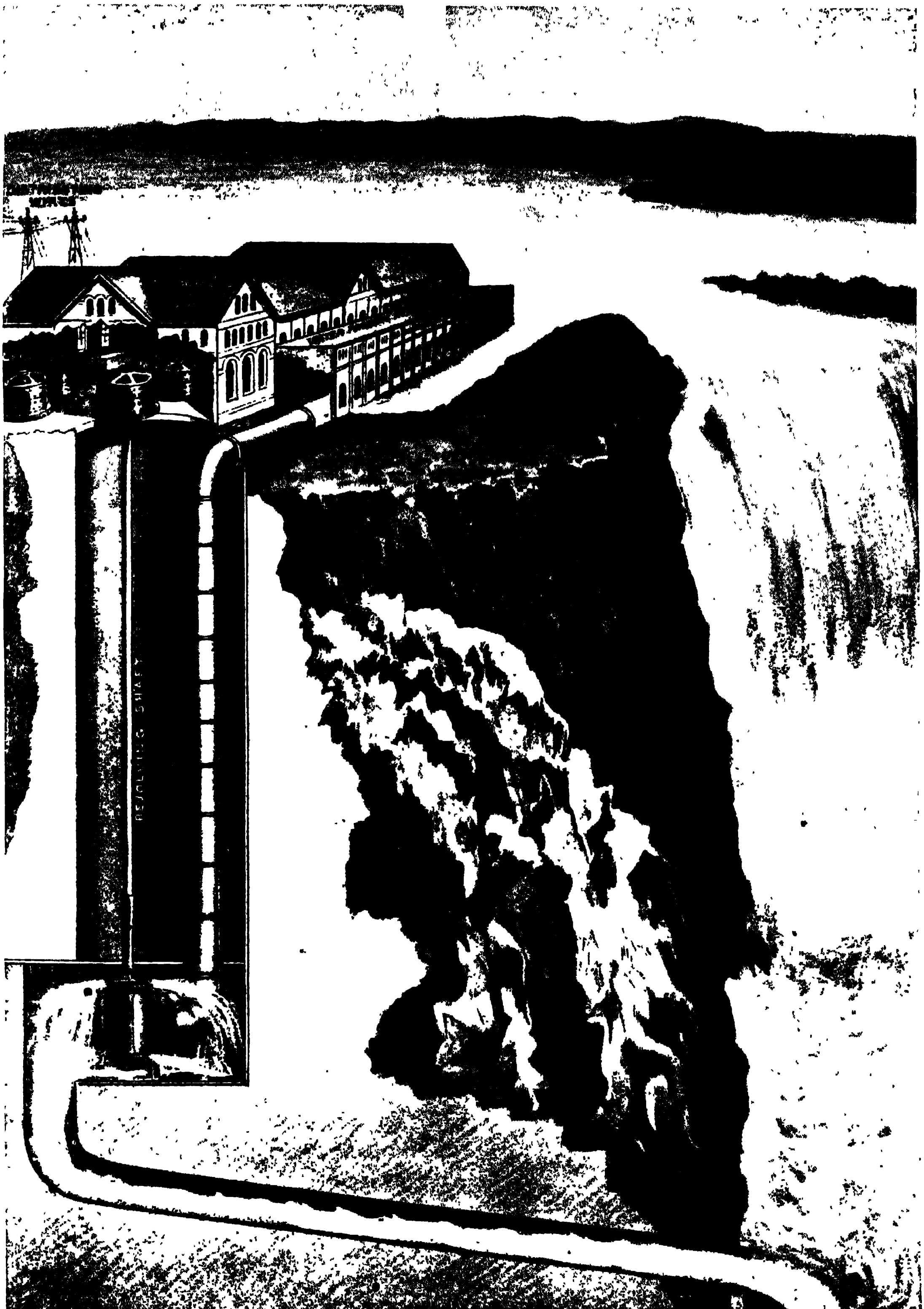
The Great Natural Source of Energy that is Practically Inexhaustible

We come now to the second great source of energy—the world's water power.

The water power here considered, it must be remembered, is that which science has rendered available. So far, engineers have decided that tidal power cannot be used economically. Great use is already being made, however, of mountain streams and waterfalls in the countries fortunate enough to possess them. Niagara is now the centre of great industrial operations. In France, in Switzerland, in Italy, in Norway, in South Germany, and elsewhere, great developments are in progress, and the term "white coal" has been coined to express the economic value of water power. In the Bavarian Alps one may find a picturesque inn lit by electricity derived from water power. The waters of the turbulent Isar, which bears fair Munich on its banks, are to be yoked to make what we are told is to become one of the greatest industrial centres of the world.

A moment's consideration of a map of the world, and of the mountains and streams thereof, will show the student that "white coal" is as unevenly distributed as coal itself, and that sometimes a coal-less land possesses water power. Water power has this advantage over coal: that it is for practical purposes inexhaustible, whereas

CHAINING THE FALLS OF NIAGARA



Niagara bids fair to become a centre of enormous natural power. This picture shows a generating station above the falls, where the water is diverted to turn a great shaft before it passes out at the bottom. The shaft works the generators, and by means of wires electric power is carried to various towns.

a fine coalfield, such as that of South Wales, may be creamed of its best within only two generations.

This broad review of the world's power supply enables us to picture modern machine industry as grouped in natural power areas, and we see the great coal civilisations standing out supreme, because based upon the extraordinary economic advantage which the possession of coal gives them. It is because the United States is the greatest coal-producer in the world that people have been attracted to her as by a magnet, and that her population has risen from ten millions in 1831 to nearly a hundred millions in 1911.

The Immense Increase in the Wheatfields of the World

We pass to the second great determinant of the distribution of the world's population. This is fertility. The great industrial populations, grouped, of necessity, upon coal and water power areas, call for enormous supplies of food and raw materials—organic and inorganic. The gigantic increase in the demand for food, caused by the multiplication of wealthy industrial populations, may be illustrated by the growth of the world's wheat crops in recent years. Here are figures of the production for the last sixteen years throughout the world:

THE WHEAT CROPS OF THE WORLD FOR SIXTEEN YEARS

Year	Cwts. of Wheat	Year	Cwts. of Wheat
1895	1,220,000,000	1903	1,620,000,000
1896	1,190,000,000	1904	1,460,000,000
1897	1,140,000,000	1905	1,600,000,000
1898	1,460,000,000	1906	1,660,000,000
1899	1,310,000,000	1907	1,500,000,000
1900	1,330,000,000	1908	1,590,000,000
1901	1,390,000,000	1909	1,800,000,000
1902	1,580,000,000	1910	1,730,000,000

There has thus been an increase of nearly 50 per cent. in the world's wheat production in half a generation. Wheat is the most prized of the grasses of which all flesh is made. It is the aristocrat of the cereals, and the staple food of the most advanced races.

The Most Extraordinary Period of Expansion that the World has Ever Known

The increase in the production of wheat is partly due to the increase of population of the nations of Christendom which we have already considered, and partly due to the rise in the standard of life of the world at large. Consumers of inferior foods in Europe have emigrated to the New World, and become consumers, or increased consumers, of wheat, meat, and other prized foods.

It is very remarkable that, although the increase in the wheat supply has been greater than the increase in the population, the price of wheat, as we shall see, has considerably increased in the period examined, showing that demand has risen even more rapidly than supply. The broad fact is that while, in the last fifteen years, the world's wheat has increased in quantity by 50 per cent., its price has also increased by 50 per cent. This is symptomatic of the most extraordinary period of industrial and commercial expansion that the world has ever known. The resources of the world are now being exploited on a scale which transcends all former experience. The quantity of iron brought to market in the world is one of the best indexes of industrial and commercial expansion. Testing the work of the world by this sure standard, we get the following measure of progress:

THE WORLD'S PRODUCTION OF PIG IRON FOR SIXTY YEARS

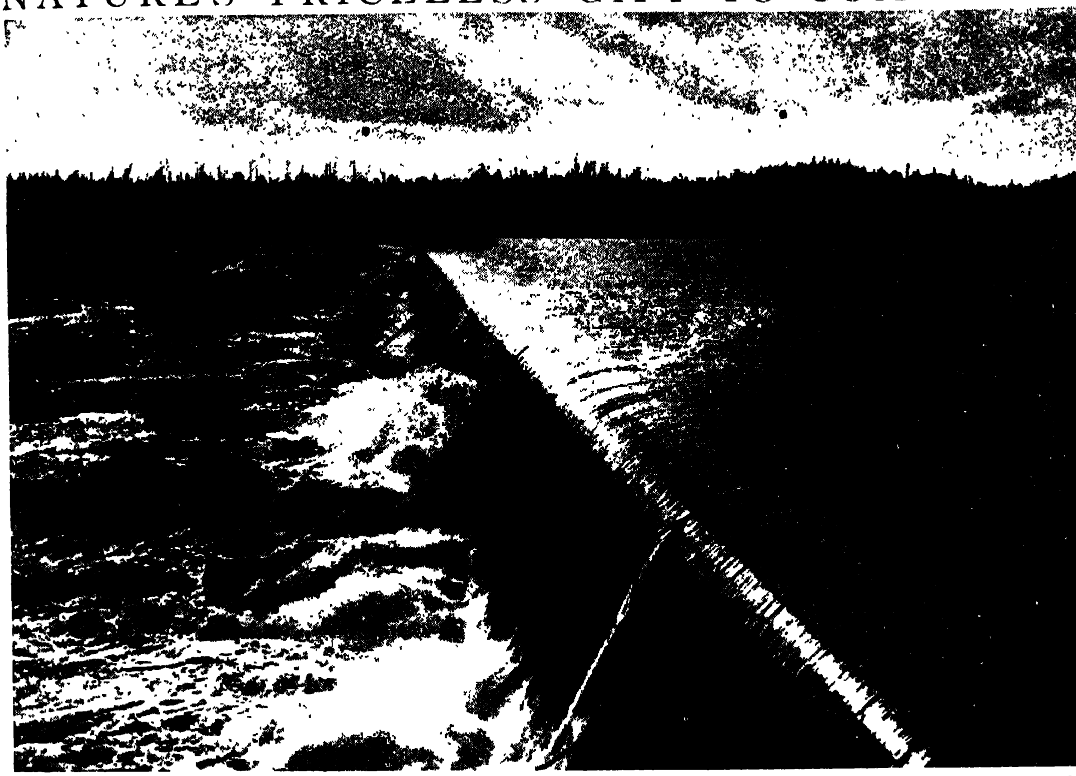
Year	Tons of Iron
1850	4,200,000
1860	6,900,000
1870	17,900,000
1880	11,800,000
1890	26,900,000
1900	40,000,000
1909	60,300,000

The Stream of Workers Ever Flowing Towards the Great Power Areas

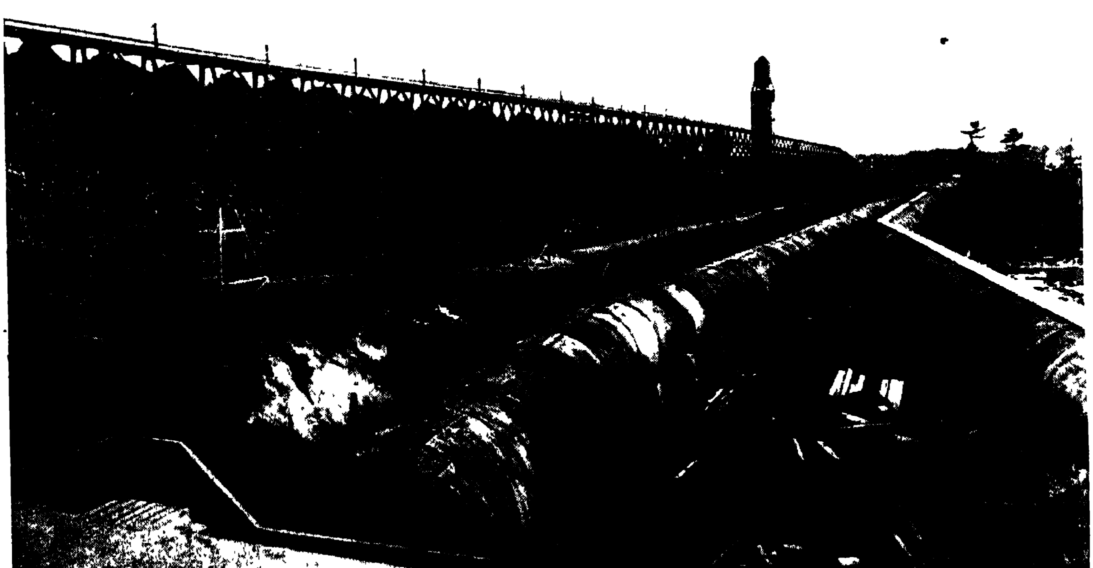
In the first nine years of the twentieth century the annual production of pig iron increased by 20,000,000 tons, and the complete figures for 1910 will probably show that between 1900 and 1910 the world's annual production of pig iron has risen by 26,000,000 tons; that is, by an amount equal to the entire annual production of the world as recently as the year 1890. These facts are eloquent of the rapid march of industry and commerce. Iron is the basis of modern work, and the vastly increased use of iron spells a marvellous addition to the world's railways, steamships, and industrial plant. This record shows at a glance the rapid rise in the standard of wealth and comfort, which is leading to an ever-increasing demand for wheaten bread.

The circumstances we have reviewed enable us to comprehend the great streams of emigration which flow from the Old World to the New. We see industrial workers attracted to great power areas, and the natural fertility of new lands—very literally "fresh fields and pastures new"—attracting from the long-settled and comparatively crowded lands of the Old World workers anxious to pass from lands where every yard of ground has been worked over to these spacious territories

NATURE'S PRICELESS GIFT TO COMMERCE



RE'S INEXHAUSTIBLE SOURCE OF POWER—A MIGHTY WATERFALL IN NEWFOUNDLAND



THE WATERFALL CAPTURED TO SUPPLY POWER TO MAKE THIS HUGE STACK OF TIMBER INTO PAPER

The forest as a source of power is coming to an end, but timber, the supply of which is inexhaustible if men conserve the forests, has boundless uses. These two photographs were taken at Grand Falls, in Newfoundland, and the water-power and timber seen here are used to make a London morning paper.

of the New World whose virgin fertility enables crops to be raised for the scratching. We see the agricultural group of emigrants going forth to help feed the world's industrial workers. As a consequence, old streams of commerce are invigorated and new streams arise. An ever-increasing number of freight cars and steamships is needed to transport the expanding surplus natural produce of such countries as Australia and Canada and Argentina, and to exchange them for the manufactured productions of industrial centres.

The Two Million People Who Move About the World Every Year

Such will continue to be the development of the world of commerce for a great part of the twentieth century. Nearly two million people a year are now transplanting themselves from one part of the world to another, and the settlement of new countries is proceeding apace. New and vast populations are growing up in hitherto unpeopled areas. There is obviously a limit to such a process, even under existing conditions; and the more the pace of emigration is accelerated with the spread of better knowledge and understanding of what the world as a whole has to offer, the more rapidly the process must end. The natural fertility of new countries, moreover, is by no means inexhaustible, and the Governments of the New World will not for ever have land to give away as a bait to settlers.

Beyond lies the possibility of such gifts by science as shall, by cheapening power, or by making power more evenly distributed in the world, lead to a new settlement of mankind on the globe. There is the possibility also of the control of climate and of fertility to an extent yet undreamed of.

The Grave Consequences of Bringing the World's Wealth to Market Unscientifically

Commercial questions of the deepest importance to man are raised by what we have considered. We have seen with what rapidity world-development is proceeding. Few secrets are now withheld from geography, and the engineer is covering the 53,000,000 square miles which is the basis of all mankind with a network of railways, rendering easily accessible all the world's remaining native fertility, all the world's forests, and such of the world's minerals and metals as can be got by discovered methods. We thus get a picture of all the world's wealth brought to market as it has never been brought before. The figures relating to the production of wheat and iron are typical of all, or nearly all, the foods and commodities required by man.

There has been a very grave consequence of this recent rapid commercial exploitation of the world, and that consequence is higher prices. We shall see, as we proceed, that an increase in the supply of gold partly accounts for the rise in prices expressed in gold, but the greatly increased call upon not unlimited supplies has been a larger factor in recent appreciation.

We have not taken sufficient thought so far in our dealings with our small world. Within a recent period of history—within the lifetime of many of those now living—man has become possessed of extraordinary powers over the forces of Nature. Armed with the powers conferred upon us by physical science, we have addressed ourselves to a world which but yesterday appeared limitless in natural resources. We have hastily ploughed over virgin soil and exhausted it, as in some parts of the United States, for example. We have laid waste magnificent forests without regard to the fact that two generations cannot restore what can be hewn in a year. We have creamed some of the world's richest and most easily worked mines, without, it is to be feared, much regard for posterity.

The Natural Supplies that have a Harvest, but no Seed-time

That is why we have seen, at the beginning of the twentieth century, an almost universal rise in prices—as compared with those of ten or fifteen years ago—ranging from necessaries such as wheat to luxuries such as sables. Timber is dear, and good timber is scarce at that. Rubber is dear, through the careless sapping of existing rubber-trees without sufficient replanting.

Lancashire, and indeed the whole world's cotton trade, is harassed by a shortage of material, because the world as a whole has not taken sufficient pains to consider the areas in which cotton could be profitably planted. Tin is dear, because the best has been taken from the world's chief supply in the Straits Settlements. The advanced prices named in long-term iron-ore leases in the United States, the richest iron country in the world, show that iron must become dearer.

The list might be extended indefinitely, for the world, quite early in the history of machine industry, has already used much of its best natural supplies of materials of every sort.

We are here concerned with matters of profound import for the future of Great

Britain and of all mankind. It is increasingly evident that industry and commerce must be carried on with a greater regard to the conservation of the world's resources, and that ceaseless endeavour must be made to promote co-operation between producing and consuming units throughout the world. The beginning of such efforts is fortunately already discernible, and the great nations are becoming more and more alive to the necessity of taking action in regard to this vital problem. In the United States, realisation of the wanton waste which has long proceeded, and of the necessity of preventing further spoliation, has led to the creation of Mr. Roosevelt's Conservation Commission. In the British Empire the Imperial Conference accepted unanimously a resolution, moved on June 16th, 1911, by Sir Wilfrid Laurier, urging the appointment of a Royal Commission to investigate and report upon the natural resources of the Empire. In Canada stern measures have been taken to prevent further waste of timber.

The problem before us is really two problems. In relation to organic supplies, such as foods, vegetable fibres, timber, rubber, vegetable oils, the problem is merely one of looking ahead and taking sufficient forethought. We can get by industry, and distribute by commerce, as much of these things as we need. With regard to inorganic supplies, the problem is of a more different order, and calls for the more serious efforts of science. A mine has a harvest, but no seed-time; and the prospect of an iron famine is near enough in the future of man to make the study of iron conservation, of the utilisation of low-grade ores, and of the economic use of such partial substitutes as aluminium, a matter of much moment to all mankind.

THE FOREST IN ITS PRIME—THE NATURAL SOURCE OF ENERGY FOR THOUSANDS OF YEARS

The age of the forest as a source of power is passing away. For years men have laid waste magnificent forests without regard to the fact that two generations cannot restore what can be hewn down in a year, with the result that timber grows scarcer and dearer.

It is the function of commerce to perform a synthesis of the world's activities; and there is no happier indication of advance in this direction than is to be found in the multiplication of international commercial conferences in recent years. When commercial men of all nations meet to consider the world's supplies of iron, of cotton, or of wool, and to ask how these things can be utilised with economy, the world is beginning to make the best use of its very limited resources.

THE CHILD WHO LEADS HUMANITY

"Out of sheltering love for the child the family is born. Out of the family come institutions of society which mitigate the harsher struggle for existence. Does it not look as though the little child has led humanity along the path to civilisation?" This picture, by Mr. T. C. Gotch, is called "The Flag."

THE FIRST HUMAN FAMILIES

The Family as the Basis of Enduring Society and the Inspiration of all that is Best in Man

THE ROCK ON WHICH GREAT NATIONS BUILD

THERE has been considerable dispute among men of science on the question whether the horde or the family was the original social unit. Remote in interest as the matter may seem, it really has a practical significance.

If we can trace the evolution of the human family, we may be able to predict the course of its future development. This is, indeed, one of the chief services of science: as Auguste Comte said, we must see in order to foresee, and foresee in order to control. If it can be shown that man was primarily a gregarious creature, and that his rude, primitive, communal life was the factor which enabled him afterwards to form family groups, there is then a possibility that the highly organised state of the future might not retain the family as its base.

Already certain socialists of the extreme school are adopting the theory of the fundamental gregariousness of mankind, and trying to make this theory a political force. They hold that the family has merely been the temporary product of a particular stage of economic development, and that with the disappearance of private property the family also will vanish. It is predicted that all children will then be cared for by society as a whole, while men and women will be able to adopt or abandon married life as their fancy may dictate.

Wild and mischievous as is this idea, it is not without some indirect support in a certain scientific theory of social origins. Lord Avebury, for instance, has for many years maintained that, as we look down the scale of civilisation, the importance of the family diminishes and the power of the tribe increases. This, some political revolutionists think, goes to prove that family life is not rooted deeply and permanently in human nature. Recent research, however, clearly shows that many famous men of science of the older generation were mistaken in regarding the horde as the original social form. The theory was mainly founded on the description of a tribe of natives in South Australia given by an English missionary, Lorimer Fison. Fison said that the tribe was divided into two classes; every man in each of these classes was the rightful husband of all women in the other class, and every woman in each class was the rightful wife of all men in the other class. The natives of Australia are savages of a very low type, and this description of their way of life was accepted as evidence that in primitive ages the relation between the men and women of the two classes was one of promiscuity, and that no family life existed.

Another very curious fact was brought forward in support of this view. About one half of the savage races, scattered about the earth, have a strange system of maternal kinship; the children take their name from their mother, and reckon their relationship only through her, and sometimes the mother's brother exercises most of the rights and duties of the father. The maternal uncle sells his nieces in marriage, and avenges any wrong done to the children of his sister.

All this was thought to show that family life was originally unknown, and that the task of looking after the offspring of brief, animal-like, promiscuous intercourse fell chiefly on the woman, her brothers perhaps helping her as regard for the tie of blood increased with the development of the mind of man. But it has already been proved that the notion of the promiscuity of the Australian native rests on an extraordinary misconception. In order to prevent the harmful effects of in-breeding, the Australian native, like nearly all races of savages, divides a tribe into two classes; men and

women of one class may not marry among themselves, but only among members of the other class. This, it will be seen, is a very different thing from promiscuity; it is, indeed, completely opposed to what is called communal marriage. Instead of degrading man to the level of the lower beasts, it shows a practical wisdom of so high an order that it is utterly inexplicable how the primitive savage could have thought it out and reduced it to an almost universal practice.

Is the Family Rooted in Marriage or Marriage in the Family?

This is one of the most mysterious things in the study of primitive society, and it will be necessary for us to examine it at some length when we discuss the science of marriage. The problem of maternal kinship, which has been used to confirm the theory of primitive promiscuity, is also a matter which can only be fully gone into in connection with the study of the later variations of human marriage. One important point in regard to it, however, must be touched on. At first glance it may seem as though we are taking facts in a wrong order in studying the family before we have dealt with the question of the institution of marriage. But marriage and family are intimately connected with each other: it is primarily and originally for the benefit of their children that men and women live together and grow into little social groups. Among many savages real conjugal life does not begin until a child is born, and thus we arrive at the conclusion that marriage is rooted in family rather than family in marriage. And if we can show that the family existed before the horde, it will be patent that we have discovered in the system of marriage the primary element of social life.

The Family is the Probable Starting-Point of Evolution

In his "Descent of Man" Darwin remarked that "looking far back enough in the stream of time, and judging from the social habits of man as he now exists, the most probable view is that he aboriginally lived in small communities, each with a single wife, or, if powerful, with several, whom he jealously guarded against all other men."

This view is now upheld by most men of science of the younger generation, and a mass of fresh evidence has been collected in support of it. It is now certain that the man-like apes live in small families. The gorilla builds a solitary nest for his mate, and at night he crouches at the foot of the tree, guarding the female and young, in the nest above, from the nocturnal attacks of leopards. The chimpanzee does the same thing; and in daytime one can see the "old folks" sitting under a tree eating fruit and chattering, while the children swing in the branches over their heads. Less is known about the orang-utang, but he is not gregarious; and as he has been found with half-grown young in his care, it looks as if he were also a good parent. These animals are more closely related to man than are the lower and more communal monkeys, and so it is highly probable that mankind emerged from the brute with a family life like that of the man-like ape, as the starting point of social evolution.

In both the man-like apes and the human being there is a long period of infancy: the higher in the scale a young creature is, the more slowly its powers of body and mind are developed; and in the case of children it is comparatively late in their life before they are able to provide for themselves.

The Little Child who led Humanity along the Path to Civilisation

So they have to be nurtured for a long period. Out of their helplessness is thus formed a bond between their parents. Out of sheltering love for the child the family is born. Out of the family, as we hope to show, are produced many of those institutions of society which mitigate the harsher struggle for existence.

Does it not look as though the little child has, in a way, led humanity along the path to civilisation?

It is easier to discover the reasons that kept man apart from man, in little scattered family groups, than it is to trace the socialising force which gradually drew men together into loose tribes. Our fruit-eating, half-human ancestors seem to have laboured under the same difficulties as the chimpanzees in getting food at certain times of the year: so they dispersed in search of it. When man became partly a flesh-eater, he naturally continued his solitary way of life. As Herbert Spencer pointed out, an animal whose prey can be caught and killed without help, profits by living alone, especially if its prey is much scattered, and is secured by stealthy approach or by lying in ambush. "Gregariousness," says Spencer, "would here, be a positive disadvantage." In regard to this point it is worthy of remark that even at the present day there are savage peoples who live in separate families rather than in

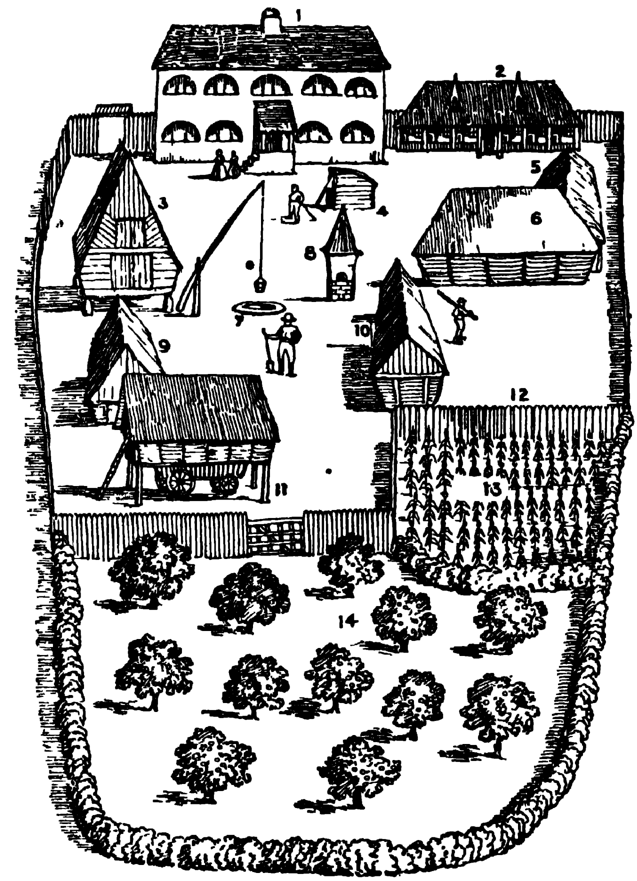
tribes, and most of these peoples belong to the very rudest races in the world. Sexual feelings, the instinctive love of children, and the customary attachment to relatives are the only ties that seem to keep them in any sort of union.

At last, then, we have reached a definite point from which we can follow, step by step, the evolution of the family systems of mankind. We have arrived among the lower hunters, who have scarcely made any important advance in social organisation. As a rule, there are no marriage laws, in a legal sense, among them, as there is no tribal power, but marriage with a single wife usually obtains, owing perhaps to the approximately equal numbers of the sexes, rather than to any objection on the man's part to a plurality of wives.

Food consists of animals killed by the men, and roots and fruits gathered by the women. By reason of the crudeness of the lower hunters' weapons the resources of the land around the camp are quickly exhausted, and the family has to wander about the world continually, urged by hunger and menaced by famine.

The husband is the ruler of the family; he buys his wife or gets her in exchange, and uses her as a slave. The children also are his property, even when they count relationship through the mother, and he frequently sells or exchanges them. His power over his offspring, however, ends when his daughter is handed over to another man, and when his son has passed into manhood. There is no system of inheritance in such a society, there being nothing to inherit, as a man's weapons are buried with him.

Sometimes, for the purposes of defence against a common foe, these scattered families now merge for a while into small gangs without a chief. But war does not seem to have been the original force in drawing primitive man into larger groups. No doubt fights for the possession of women sometimes occurred between two or three males; and all the members of a family may have sometimes combined in driving away a strange family which had invaded its hunting-ground. Yet it was not by quarrelling but by rejoicing together over an abundance of food that men came to acquire feelings of wider fellowship. At present, the lower hunters are usually confined to the hard, bare places of the earth, where only for a brief season of the year Nature is generous. In lands where conditions of life are easier, and game and fish are plentiful, are found the higher hunters. They are more numerous than the lower hunters, because larger supplies of food have enabled them to expand; and on the spots along the coast, where their resources seldom fail, they have gathered into settlements. The household is still the strongest bond of society, but on the household is now built the primitive village community, and these communities are connected into a loose tribe.

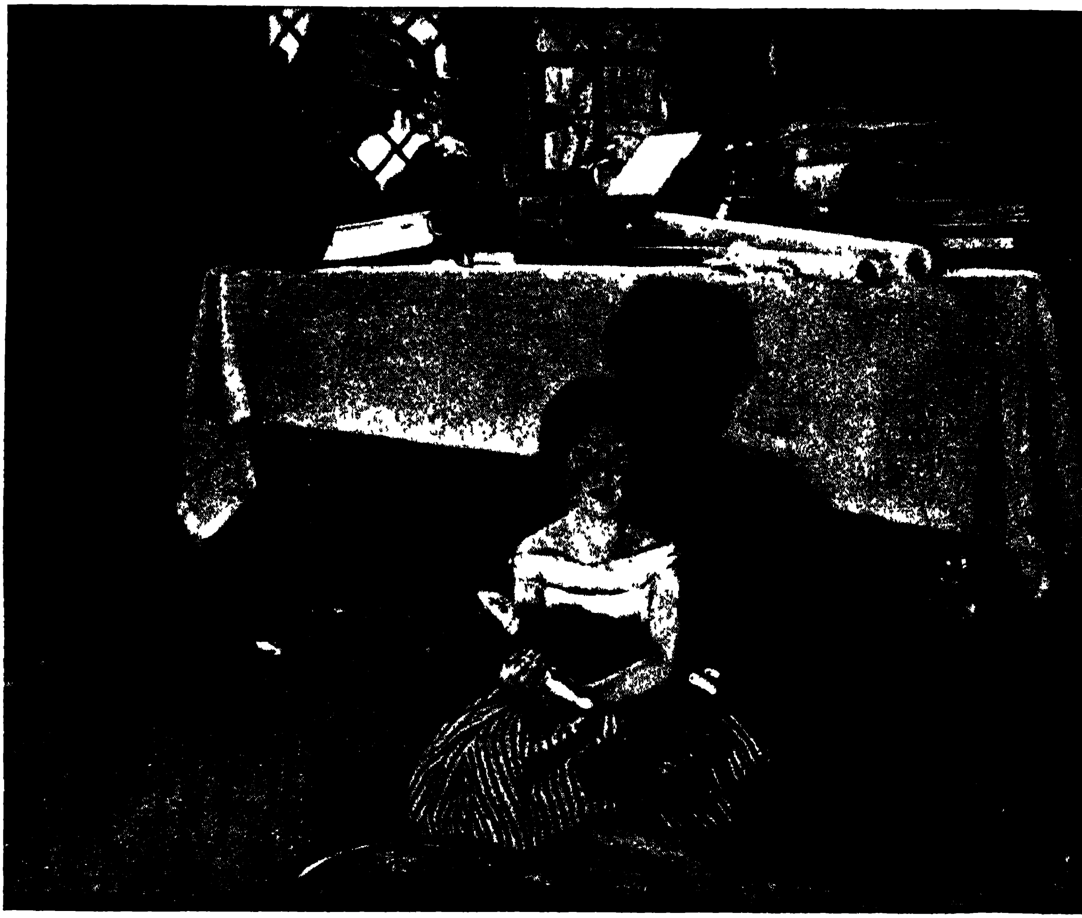


THE PLAN OF A COMMUNAL HOME STILL EXISTING

This sketch was made of a homestead in Bosnia, and the buildings represented are 1, common dwelling house; 2, summer dwelling house; 3, granary; 4, goose house; 5, cow and goat house; 6, distillery; 7, well; 8, oven; 9, stables; 10, swine stall, 11, maize loft, 12, paling, 13, maize; 14, orchard.

In this stage of culture the chief elements of human society have been evolved, but the family remains somewhat rudimentary. Husbands and wives have both reached a higher degree of skill in industry, and

things are made not only for family use but for exchange. In many cases the family has lost its special hunting-ground, the territory now being the property of the clan or tribe. The position of women, however, is still very low. Wives are bought, and treated as slaves. Daughters are a source of profit, and sons of power. For the era of warfare now begins: abundance of food leads to the increase of population; there are rich hunting-grounds and fishing-grounds to be won, and slaves are becoming widely to obtain. Large families become very profitable to men with great flocks and herds: the boys are cheap herdsmen, and the girls are very serviceable in the house. The invention of the finer domestic crafts increases the economic value of woman. In some pastoral tribes a settlement is made upon her, and if her married life is unhappy her kinsmen gladly receive her back. For the family has now gained a remarkable steadiness and strength. In its herds or flocks it has a personal property of



THE MOTHER TO BE—FROM THE PAINTING 'WHERE SHALL WISDOM BE FOUND?' By Mrs Young Hunter

useful. And then, with permanence of settlement, ancestor-worship develops; and this often makes the male a much more important member of the family than the female.

Out of the chase of the higher hunters is evolved the tending of flocks and herds. As this is always, like hunting, the business of the men, the woman at first continues in a low position in the family. She is still bought; and as a man's herds increase he is able to buy more wives. It is among pastoral peoples that polygamy begins very high importance. Petty but incessant tribal feuds over pasturage rights and the theft of cattle interfere with the development of political institutions, but, besides making home life more stable and larger, and linking closer together the older and younger generations, the acquisition of property stimulates man to undertake a more effective advance towards civilisation.

Some races have never learnt the art of the herdsman, but, while still hunting and fishing in settled communities, have turned

to farming. This has happened in certain luxuriant regions in tropical or semi-tropical climates. The most progressive peoples, however, took a less abrupt and broader path, leading up to a wider prospect. Wandering slowly in large and stable families, in search of moist rich pasturages for their herds, they settled on the alluvial soil of great rivers, and began to till the fruitful earth. Nearly all the work of farming fell on the women and girls —the men and older boys having to tend and guard the herds. Some writers think that woman was the discoverer as well as the agent in the development of primitive tillage. This is only a probability, but if woman was the author of the mighty, civilising power of agriculture, she has been indirectly rewarded by the general improvement which her work effected in the organisation of the family. By carrying on both farming and stock-breeding, the peoples living in well-watered lands obtained ample and regular supplies of food. Population, therefore, increased at an extraordinary rate; the great patriarchal family was developed, and, in especially favourable circumstances, the foundations of modern civilisation were laid.

The Foundations of Modern Civilisation Laid in the Family Community

The rural family community is one of the most important of social forms and one of the widest spread. In ancient times it existed, with modifications, from China to Britain. In the Orient it has survived great political revolutions and foreign conquests, and it has adapted itself to urban conditions and industries; it is the force behind ancestor-worship, and, as such, is largely responsible for the marvellous expansion of the multitudinous Chinese race.

In Europe the great family community has now been generally destroyed by the forces which have built up our modern industrial civilisation. Yet in the Balkan States, where for centuries civil law and political institutions were wiped out by the Turkish invasion, the Southern Slavs have preserved the chief element of national life by holding firmly to the old traditions of family fellowship. Some writers of authority regard the type of society founded on the communal family as that which is most conducive to the happiness of mankind; so it may be worth while describing the family community as it still exists in the Balkans at the present day.

It is a very big family, including cousins and more distant relatives, and the management is in the hands of the oldest member. His authority is great, but it is used in a fatherly way: he represents the family in the village council. All the property is held in common, and all the work is done in common. The men perform the hardest labour in the fields, such as ploughing, reaping, and digging; the women do the housework, and make clothes, and help in sowing and harvesting; the children tend the flocks. Save for a few iron tools and machines and utensils, the family does not buy anything. Provisions, clothes, boots, bedding, wooden ware, pottery, are all produced by the community, and their houses are built by the men.

The Family Organisation that Prevailed for Centuries in Europe

The work is mapped out, and the workers selected by the assembled family. All income and personal gains are paid into a common fund, which is not divided equally, but given out to members according to their necessities. When, for instance, one of the family marries, the community bears all the expenses. If a member leaves the family, he loses his rights; but if the community grows too numerous a division is generally agreed to, and the property is split up.

Undoubtedly, in a family organisation of this kind, most of the social problems of the present day are solved, except perhaps the problem of progress; and its extraordinary strength is shown by the fact that it survived a long period of war, defeat, and oppression. Indeed, it lasted, in various modified forms, throughout a large part of Europe until about the end of the Middle Ages. In the rural tracts of Russia, Hungary, and Austria it endured long into the modern era.

The Growth of the Great Family in the East and its Break up in the West

Only in Japan and China, however, has the great family developed from a communal life founded on agriculture into an industrial organisation. In China, all the earnings of near kinsfolk flow into a common chest, which is managed by the patriarch. In Western Europe, through a variety of causes, religious, political, and economic, the great family has broken up, and, by a strange path, returned to the primitive grouping of two parents and their children.

Before discussing the small modern family it will be instructive to notice a new and admirable system of family co-operation found in Italy. It is an adaptation of the ancient rural family community, with a

more thorough division of labour and more freedom of life. In one case the family possessed an hotel, managed by the elder brother. In a farm close by lived a sister, who cultivated the common land. One brother was a baker, working in the annexe of the hotel; two more brothers, a smith and a carpenter, dwelt in workshops; and two others, a military doctor and an officer in the Engineers—both married—lived in distant towns. The six brothers and sister had a common purse, and shared the income and expenditure; the two military men, it is true, brought in nothing, as their pay was small; nevertheless, they shared in the common property. This seems to be a successful essay, under modern conditions, in preserving the strength derived from family communism, while allowing the individual members to branch out on independent careers. It requires, however, the possession of family property in the first instance, or considerable contributions to the family fund; and a spirit of self-sacrifice must animate the workers in the group when there are some members who do not bring in anything to the common fund.

The Modern Workman who goes out to Win a Living as the Wandering Hunter did

As a rule, the small modern family is not held together by the possession of common land. The majority of men to-day face life in circumstances quaintly resembling those in which their remote ancestor, the wandering hunter, went forth to win a living and a wife. With a few tools, perhaps, and some skill and knowledge, they go out into the industrial or commercial world, sometimes with their father at hand to guide them, but often alone and adventurous. When they are ready to marry, they do not have to obtain a wife by purchase, or work for years for the father of the young lady, but marriage still remains an expensive matter. Not infrequently in our great cities the resemblance between the modern workman and the primitive hunter is still more drawn out. He moves away from his home and settles in a strange district in order to be nearer to the spot where he gains his livelihood; and, if he is very poor or unfortunate, his wife—like the wife of the savage—may also have to work outside her incomparable sphere.

This degradation of the mother has a deplorable effect on the health and training of the children. The organising influences of the household are destroyed, and there is left that sorry piece of social wreckage the unstable family of the modern era. Families of this unstable type appeared in large numbers in England on the breaking up of village communities. This occurred in the reign of the Tudors, when farming went out of fashion, and a great deal of the country was converted into pasturage for sheep. There was, again, a widespread shifting in the industrial grouping of the people when steam machinery was generally applied to manufacture.

The Root from which nearly all the Disorders of Modern Society Spring

Undoubtedly the great industrial revolution had a disastrous social effect; it did more than any political force has done to create the unstable family—the root from which nearly all the disorders of modern society spring. We still have among us a drifting multitude of men and women who have become disconnected atoms in the life of the community, bound by no ties of duty or responsibility, and often incapable even of self-maintenance. A system of Poor Laws has been constructed to remove the symptoms of this terrible social disease, but these laws do not revive the old traditions of family life, to the loss of which are due so many of the social maladies of our time.

Happily, the English family, as a whole, has by its own intrinsic strength survived the shock of the change, and reorganised itself on another foundation. Instead of becoming enfeebled by its severance from a common landed property, it has gained in spiritual force. It is a fine proof of the strength of the modern family that it is able to send its sons and daughters away to the ends of the earth, without impairing the invisible bonds which unite them. It is from the stable family of the new type that the wonderful colonising power of our Empire is partly derived.

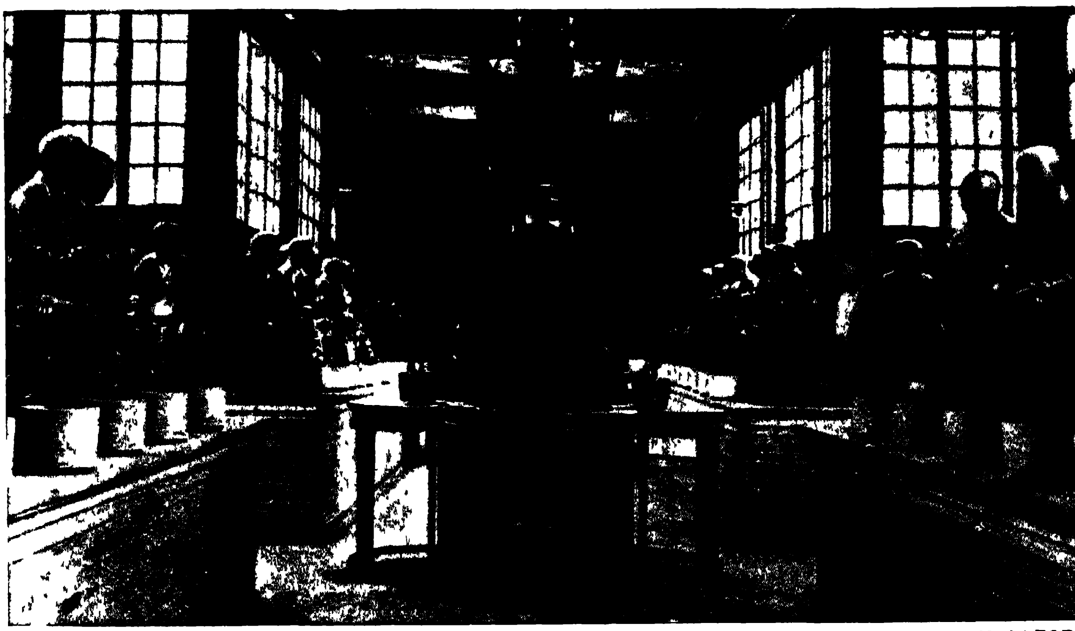
The Strength of the Tie of Family Love which Supports the Modern State

One important form of co-operation still prevails in modern family life: the husband and grown-up children provide the income, and the mother looks after the home and the younger children, and manages and spends the household money. Among all our wage-earners there is, fortunately, an increasing tendency for women to devote themselves to the work of housekeeping; they thus become the centre of the home, entirely replacing the ancient patriarch, and to their emancipation is perhaps due the new spiritual force of the family tie.

The modern stable family is, no doubt, open to the play of powerful outside influences which at times seem to menace it.

It is in the school and the office and the workshop that children now acquire most of the knowledge and skill with which they make their way in life. They therefore tend to display a much more independent spirit than the young members of the old family community possessed. When, however, the home life of modern children is sound and happy, they learn to combine with their regard for personal liberty the sweeter feelings of loving duty and affectionate co-operation. In many cases, when they go out into the world, they are still united to their family by the work which they do. The family traditions which used to obtain in connection with the possession of land are now continued in connection with a common same thing occurs generally in all industries in which a fair amount of skill is required. A continuity of work binds the generations together, and affords a basis for continuous family life as strong, if not as tangible, as that of landed property.

No doubt it was on the industrial basis that the small modern family of the stable type was partly founded ; but we must not, while allowing for the play of economic forces, omit to take into account the transcendant and primary factor of family life. The family has survived all kinds of changes and disasters ; it has turned the primitive superstitious dread of ghosts into the noble pieties of ancestor-worship ; it has been especially instrumental in developing the



WHERE FAMILY DEVOTION SURVIVES THROUGH MANY GENERATIONS—A HALL OF ANCESTOR-WORSHIP IN CHINA

calling. In trade and commerce there is often a continuity of work, linking generation to generation in a common interest ; nearly all the sons of professional men enter the professions ; but it is among the industrial classes, to whom their calling is their one great possession, that the family tradition is generally maintained.

Sometimes this is due to economic causes, similar to those which produced the old family communism. Among many coal-miners, for instance, it is customary for fathers and sons to work together ; by this means they earn more money or obtain advantages in getting free housing or quick employment. In the textile trades sons also follow their fathers' calling ; and the finer elements of civilisation, and in teaching men the high value of mutual aid and co-operation. Future alterations in the government and conditions of society may affect it, but they cannot destroy it.

For the family is love. There are few persons whom the sight of a strange, unknown, helpless baby, a strange, unknown, enfeebled old woman, would inspire with a new energy in life ; but many a mother would work herself to death for her own child, and many a man would toil beyond his power to save his mother from want. Only the passions and affections which create and maintain family life can bring into play the best qualities of man and woman. Destroy the family, and the State falls to pieces.

CLASS-HATE—A TERRIBLE FACT IN SOCIETY

The spirit of class prejudice and selfishness, so finely embodied in this picture of the French Revolution, by Mr. Fred Roe, R.I., is the worst enemy that the science of ennobling human life has to face.

WHAT EUGENISTS ARE NOT

The Test by which all Human Institutions must be Judged—the Quality of Life They Produce

THE BEST LIFE FOR THE GREATEST NUMBER

EVER since man reached human estate there have been Eugenists, or he would not be here now; and we need but glance at the lower animals or at the vegetable world to see the eugenic principle dominant.

The great and ancient races of man, which have survived all vicissitudes, such as the Jews and the Chinese, are pre-eminently races of Eugenists. The Jews, above all, guard their youth, prepare and educate them for parenthood. They respect the expectant mother; do not allow her to do other work than her sacred own; and they will not allow her, when her child is born, to work in a factory and leave the child unnursed by its mother. Thus, in extremest poverty, they have the lowest infant mortality. They forbid child labour, wholly bar the abuse of alcohol, so that the drunken Jewish mother is absolutely unknown, and the drunken Jewish father has only lately been seen, in one or two cases, in London and New York; and their freedom from sexual immorality protects them from the diseases which are commonly associated with it. They thus avoid the racial poisons which tend to sap the vigour of all races that do not keep them at bay.

But it is only within our own time that the eugenic idea became explicit and directive among modern nations, and only within the last few years that a small but daily increasing company of people have set themselves wholly and determinedly to what they regard, and will ere long teach the whole world to regard, as the divinest of all causes. These are the people called Eugenists, who have surveyed the past and seen how the question of population, its quantity and its quality, has been the reigning rule of history; and whose survey of the past, and the indications it furnishes of the probable nations of the future, have led them to proclaim a "new" doctrine—far and away the oldest in the world, dating from the first act of primitive life—which they call Eugenics, or Good Breeding.

The term was introduced now nearly thirty years ago, as we have seen, by Galton, who met with so little response at the time that he turned aside to other studies, such as those of finger-prints and composite photographs. But about seven years ago he was persuaded by the Sociological Society to lecture on eugenics, declaring that eugenics must be made a factor in religion and in national policy. It has indeed always been a factor in religion; but there was great and growing need for Galton to teach that religion must more clearly concern itself with the supremely religious project of making nobler people, now that science has made more than a beginning with the revelation of those natural laws which furnish so much guidance in the project, and come so powerfully to the aid of religious dogma, traditional observance, conventional education, public opinion, and the other forces which seek to make men worthy, or keep their unworth under control.

It then fell to the lot of the present writer to introduce the name of Eugenists for those people who set themselves, as the supreme end of all policy, the making and maintaining of the largest possible number of the finest possible people, and who deliberately assert that this is the end of ends, by which all other ends, all means whatever, all political parties, all institutions, old or new, all dogmas, all human practice, conduct, and belief, will in the last resort be judged. How much life, and of what quality, did they produce?

The word "eugenics," and the appellation Eugenist, will very soon become part of the stock vocabulary of politicians, and will be as familiar to the eye and ear as words like "Evolution" and "Sociology," once

so strange and uncouth, have now become. As is the rule, these new terms, expressing immense ideas, must weather a period of misunderstanding and misuse, powerfully contributed to by injudicious advocates, by hangers-on who want to turn the new thing to their own ends, by the stupid at large, and by cynics and enemies whose one chance of success in fighting any new truth or any new advocacy of truth lies in falsehood. Eugenics has already had its full share of all these dangers, not least that of unscrupulous and monstrous misrepresentation, and it behoves those who realise that this is a winning cause—on whose side they may as well range themselves as soon as possible—to get right ideas of it from the first.

The Degradation of a Noble Name in the Interest of Many Bad Causes

The writer is naturally jealous of the honour and utility of this name, which all manner of people are now applying to themselves and others, and which is at one moment used as an argument against infant mortality, and at another as an argument against those who seek to abolish infant mortality. When one finds that the "better-dead" school, as they may with convenient ambiguity be termed, call themselves Eugenists in protesting that we must save no more babies, as they are not worth saving—the time has evidently come for a plain statement of what this word means. It is unfortunately much easier to coin a name than to prevent its abuse, but one cannot simply stand by and permit the prostitution to the interests of national infanticide, alcoholism, neglect of children, militarism, class-hatred, and the devil knows what other of his works—of a word which was coined in the service of Life.

Indeed, the case is now such that no sooner have we declared what the people called Eugenists are than it is necessary to make quite clear what they are not. That task will abundantly occupy us here.

The People Called Eugenists and the Doctrine Called Materialism

In the first place, the people called Eugenists are not committed by their creed to any form of materialism or denial of whatever exists beyond the material world. No one has the right to draw any such inference from the fact that, for instance, Eugenists insist upon the importance of heredity even in the realm of our moral nature. If it can be shown that children tend to inherit their parents' good temper or cruelty, or tenderness or dishonesty, and if Eugenists insist that these facts are to be reckoned with in education and in our national policy, they are neither to be blamed for discovering and proclaiming the laws and facts which, being natural, are therefore necessarily divine; nor are they to be accused of asserting that the moral influences of human life have no influence and are to be discounted. It is undeniable that people who profess and call themselves Eugenists have employed the facts of heredity in order to deny the existence of conscience and of moral responsibility, to declare that all the attributes of mind and soul are really material, and to deny any value to what we usually call the spiritual forces of the world's life. All such people are here repudiated.

Secondly, the people called Eugenists are not committed by their creed to the outrageous misunderstanding of Darwinism for which Nietzsche is principally responsible, and against which Darwin explicitly defended himself. No worse or more abominable rendering of eugenics can be imagined than that which asserts that mankind is degenerating because the law of natural selection has been abolished, and a "sickly humanitarianism dating from Rousseau"—as a dean of the Church of England has been heard to assert on a eugenic platform—has disastrously replaced it.

The Conditions of Civilisation which Modify the Harshness of Natural Law

This kind of teaching involves so many absurdities and cruelties that it cannot be dealt with in this preliminary statement as it demands. Humanitarianism, for instance, is somewhat older than Rousseau, and has been credibly associated with the Founder of the Christian Church. The law of natural selection, or survival of the fittest, has not been abolished, only its working has been modified by the conditions of civilisation. The law that the fittest, *in the conditions*, survive is one of natural necessity, and can no more be abolished than the twoness of twice one. There is no evidence that mankind is degenerating; but if the law of love, older than any Church or creed, or than mankind itself, were abrogated, there would forthwith be an end of us, seeing that without love no baby can survive its birth for twenty-four hours. And as for the supposed opposition between eugenics and philanthropy, the truth merely is that eugenics seeks to make philanthropy more philanthropic, by directing it into wiser channels, and preventing it from aiding the diseased and feeble-minded to multiply their calamities more rapidly than ever.

The people called Eugenists cannot possibly afford to sneer at the spirit of humanity, whoever invented it, for only through that spirit, and only by appealing to those who possess it, can this humanest of all ideals, the making of man more human and more humane, be realised.

Thirdly, not only has the Eugenist to repudiate those friends and enemies who wish to have done with mercy and charity and mutual service, or who accuse him of wishing to have done with them, but also he is attacked as an enemy of morality by those who declare that he seeks the abolition of marriage. And if he vigorously denies this, as the present Eugenist does, he has to face the fact that many of his so-called friends do indeed desire to abolish marriage, and that many enemies of marriage begin to talk eugenics because they hope to discredit marriage. In the upshot, they simply discredit eugenics.

TYPES OF A GREAT EUGENIC RACE—THE JEWS, WHO GUARD THEIR MOTHERS AND CHILDREN, and, amid extremest poverty, have the lowest infant mortality of all the races in the world.

Now, the Eugenist has indeed asserted his right and intention of judging all human institutions by his criterion—the quality of the human life they produce—and not only does he bring marriage under his purview, but he allows himself to praise certain aspects of this institution, as found in certain countries or classes—say, the responsibility it exacts of fatherhood—while he also condemns other aspects of it, such as marriage for money. Undoubtedly the Eugenist declines to accept conventional, legal, or ecclesiastical standards of judgment in this or any other matter, but he is necessarily bound to study the history and functions of marriage in the course of his inquiry, and that leaves him no choice but to recognise the principle of marriage as the foremost and most fundamental instrument of his purpose. Only, as we shall see, it must be eugenic marriage. The Church and the State and public opinion may permit the marriage of a feeble-minded girl of sixteen, or a marriage between a diseased inebriate and a maiden clear-eyed like the dawn, but the Eugenist has regard to the end thereof; and he is false to his creed and his Deity if he does not declare that these are crimes and outrages perpetrated alike upon the living and the unborn. If this is to "attack marriage," then he does attack marriage. But this is rather to make a stand for marriage against the influences which seek to destroy it.

The people called Eugenists require to repudiate their popular interpreters in another aspect also, for they find it said that they "wish us all to be forcibly married by the police," or that they wish to substitute for human marriage and parenthood

"the methods of the stud farm." So far as this country is concerned—and so far as one's acquaintance with the literature of eugenics elsewhere goes—it may definitely be said that no one who has made the slightest contribution to, or performed the slightest service for, eugenics has ever made such idiotic proposals. And it is exceedingly difficult to find any excuse for one or two well-known comic philosophers, who now have hold of the public ears, and who reiterate, year in and year out, these gross misstatements of the eugenic creed.

The High Cause of Friendship between Classes and Nations

Fourthly, just as the people called Eugenists must not be drawn into the service of international hatred by being hailed as conscriptionists, or the advocates of universal military service, so also they must repudiate those who seek to identify them with the cause of class hatred. Surveying the whole disastrous field of sham-eugenics, one is inclined to regard this as the most dangerous and menacing at the present time, not only on its own demerits, but because such a number of professing Eugenists, including many whose position makes them influential, are to be found among the ranks of those who seek to increase class-contempt and class-hatred on the ground that the "upper classes" are really upper in the vital and biological sense, and that increased attention to the needs, especially the children's needs, of the "lower classes" means national degeneration. It must be clearly stated that this spirit of class-prejudice and selfishness, which underlies the so-called eugenic activities of many professing Eugenists, is the worst of all the enemies that eugenics has to face.

The Spirit that would Poison this Book if it were to Creep into it

There is no trace of this spirit in the writings, there was none in the conversation or the character, of Sir Francis Galton. It is nothing other than the introduction of the rankest poison into the young life of eugenics, and it must be fought at every turn. If ever and whenever the reader detects in these chapters any trace of the spirit which values human quality according to its origin in any class or sect or race, or of that which decries or denies fine qualities because they are displayed in a scion of a noble house, or because they are not displayed in a scion of a noble house, let him turn to something else, and wash his fingers first. There is poison in the leaves wherever this spirit of class manifests itself.

It is true that some of the researches of Sir Francis Galton, and of those who have worked at the problems of human heredity by his pioneer methods, have led to the conclusion that ability is a special characteristic of the upper classes; and this conclusion is loudly proclaimed, as is quite natural, by those members of the upper classes who least confirm it. But, as we shall see, it was and is impossible, by these methods, to disentangle the influence of heredity, and that of the superior nutrition, sleep, air, light, education, traditions, opportunities, influence, and perhaps a few score more factors, which characterise the well-to-do, and must obviously be allowed for if any such conclusions as these are to stand. In point of fact, the study of heredity by the totally distinct methods of the present day lends no warrant whatever to the conclusions which have found so many interested friends; and, in any case, if the upper classes were really upper, the last way in which they could prove it would be by trying to keep the lower classes lower.

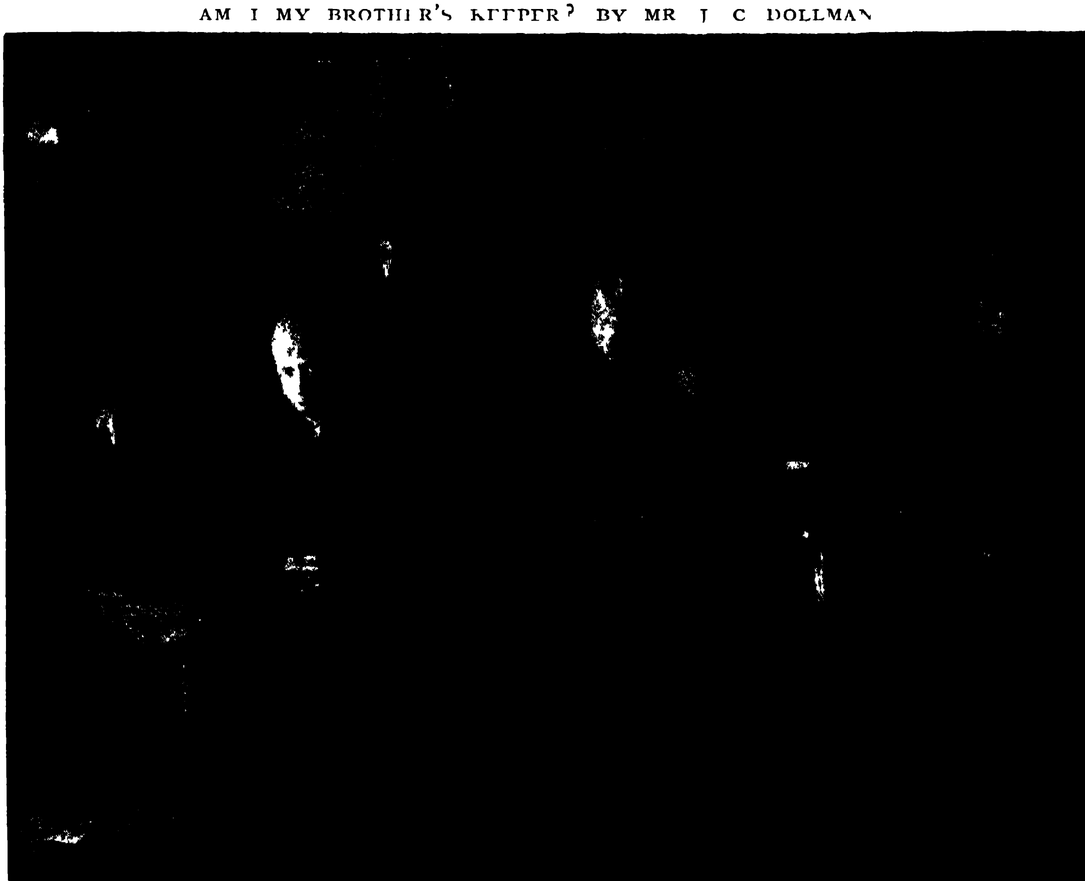
The Eugenist is too Busy being a Eugenist to be Anything Smaller

The people called Eugenists, therefore, do not include those who find in eugenics an excuse for the revival of snobbery, those who have adopted their misunderstanding of it as an alternative against what they misunderstand as Socialism, or those who, in the interests of Socialism, seek to use the facts of heredity as an argument against the House of Lords. The Eugenist cannot be a partisan. He is for the utmost of the highest life, wherever found, however obtainable; and if the true Eugenist is asked whether he is an Aristocrat or Democrat, anti-Socialist or Socialist, Monarchist or Republican, Conservative or Radical, he can only reply that he is much too busy being a Eugenist to be any of these other things—except that he is conservative in his attitude towards healthy stocks of mankind, and radical in his proposals regarding diseased ones.

Fifthly, the people called Eugenists are not opposed to popular education. This is the newest form of fallacy to which some of the foregoing errors have combined to give birth, and it is a fallacy for which many who call themselves Eugenists are responsible. The present writer dealt with this matter in a paper read before the British Association in 1911, and portions of that paper are here quoted. It is indeed true that the people called Eugenists declare that education can educate only what heredity

AM I MY BROTHER'S KEEPER?

AM I MY BROTHER'S KEEPER? BY MR J C DOLLMAN



THE DOSS HOUSE—BY MR TOM MOSTYN

The painting by Mr Dollman showing the outcasts on the Thames Embankment has been presented to the New York Board of Education by Mr Alfred Mosely

gives; that the feeble-minded child, for instance, is non-educable, and that only the remedy proposed by what we have termed negative eugenics—the discouragement of parenthood on the part of the unworthy—will solve the problem of the feeble-minded. But this article of the eugenic creed is far indeed from warranting what too many people have lately begun to assert—that education has been tried and found wanting, that genius and talent will always out, that there have thus been no "mute, inglorious Miltons," that, in short, education really effects nothing, and even that efforts to save and educate the "unfit" are worse than useless because they handicap the "fit."

The Essential Partnership between the Eugenist and the Educator

The gravest disservice has already been done to eugenics by partisans of this ignorant and arrogant temper. They have already gone far to alienate from sympathy with eugenics all the educational forces in the country, from the leaders of the great educational profession to the less conspicuous but no less valuable members of the rank and file. These all know that education is worth while, though they needed no statistical calculations to tell them that children vary in the amount of profit they derive from education. It is quite certain that the aims of the people called Eugenists will never be achieved save with the cooperation of those who educate the nation's youth, and through their conversion to the eugenic creed, so that they in turn may teach it to those who are in their charge.

The educator is, of course, indispensable in the eugenic interest, *in every way*, and certainly not least in the case of defective children, even granting that, as teachers know much better than their new would-be tutors, these children cannot respond to their educational opportunities. The nation's duty in regard to such children becomes most urgent when they attain the age of puberty, and not only their own interests but those of race are at stake.

The Children who grow up to Make or Mar the Future of the Race

Here, it is clear, the possible courses are various, depending on the needs of the individual child. We must make the profoundest discrimination possible between one child and another, and only the educator, with one psychological and one medical eye, can perform this task. Only he, through his thorough, expert, and prolonged observation, can distinguish between the various types of child: those who must on no account be permitted to enter and form part of the community, since they will injure it, and it will injure them; those who may enter the community under certain conditions; those who are merely backward or dull owing to poor nutrition, lack of sleep, frequent absence from school due to illness, or other causes which may have nothing to do with heredity, or with any risk of transmitting their misfortune to posterity, and which may be remedied by appropriately continued care. The Eugenists who inveigh against educators and education are those who lay eugenics open to the imputation that it would frequently involve the locking up for life of dull or backward children who were merely suffering from interference with sleep, educational overpressure, or lack of some vital but subtle ingredient of the diet. But the responsible Eugenist fears such a result as much as any one can; and instead of criticising or maligning education, he says to the teacher: "Yours must be the verdict." Daily for months or years the skilled educator will watch and treat such children, aided by the school doctor; and if, at adolescence, it is found that the children do indeed suffer from a *natural*, and therefore *incurable* and *transmissible*, defect, the advice of the Eugenist must be followed. The educator is essential in the discharge of this duty.

The Great Moral and Social Questions that Eugenics has to Face

No; it is not less education we need, but more, and not least the education of those very imperfectly instructed Eugenists who have already gone far to alienate every teacher and psychologist in the country.

Sixthly, the people called Eugenists are not among those who have boldly interpreted the recent study of alcoholism to mean that all interference with or control of the drinking habits of a nation leads to degeneration, and therefore that, in the interests of Eugenics, all legislative control of the liquor traffic must be abandoned. The argument is that a nation becomes sober only by the use of alcohol gradually weeding out those stocks which are liable to abuse it, and that thus the influence of control of the liquor traffic, in any degree, is only to permit the survival and multiplication of stocks which would otherwise have been mercifully extinguished, and will provide appalling calamities in the future, when their morbid appetites can no longer be controlled. This is no parody, but the statement of a view which has been widely disseminated, and is freely quoted

THE WEALTH OF THE COTTAGE HOME

This picture of "Maternity" is by Mr. Walter Langley, R.I., and is the copyright of Messrs. Vivian Mansell & Co.

by writers on these subjects. What the real relations are between eugenics and alcoholism we shall be more likely to ascertain, in due course, by studying the subject in exact fashion, as pathologists and toxicologists have done during the last decade.

It must be clearly understood that there is as yet nothing that can be called orthodoxy in the science and practice of eugenics. No student of the subject can do more than assert what he sees and believes. No authority can be quoted as final, for eugenics rests upon the conclusions of other sciences, and is bound to grow and change. Difference of opinion in such matters is not only inevitable; it is also desirable and healthy, and leads to progress.

But it is necessary to protest with all possible force against all claims to the name and sanction of eugenics which thereafter put eugenics second to some other creed or prejudice or passion, and make the divine thing serve the undivine. It doubtless is the case that different races of mankind differ, on the average, in their natural value. Here is a problem for the Eugenist. Should the higher race exterminate the lower; and, if so, how? Should the members of the higher race intermarry with those of the lower so as to raise the lower; or will this mean only the degradation of the higher? What kinds of criminal law, marriage law, property law are necessary in the United States of America or in South Africa in such cases? These matters are the most practical and urgent and momentous in the world, for the clash and fusion of races is inevitable, and is upon us as never before in human history. So also with the problems within any nation or society, the clash of class and class, sex and sex, interest and interest. All these not only have their eugenic aspect, but in the long run their eugenic aspect is the whole of them—not for the individual, who naturally has himself and the present to think of, but for mankind and its future.

Now, though our experience is very brief, and scarcely runs to a septennium

as yet, it is quite unequivocal in showing that eugenics, with its doctrines of the supreme importance of heredity and parenthood and childhood, can be forcibly used, and will be more widely used, in the interests of the publican and the puritan, the white man and the black, the "hanging judge" and the lenient judge, the repeal of the divorce law and the extension of the divorce law, the House of Lords and the abolition of the Peerage altogether, the upper classes and the lower classes, war and peace, *laisses-faire*, and copious and hasty legislation. Instances of all these and many more could be cited. At any moment, one feels, eugenics might almost become a party question and a party cry, and the Eugenist would have to murmur "Ichabod," give up all his study of the past and his dreams of the future, and take to breeding mice or peas.

None of this will do. Eugenics is for all mankind, and for all the future. Its concern is to make fine men and women, and to multiply their number, anywhere and everywhere. It is not to be judged by or adapted to any other criteria or canons, or aims or ideals but its own. It is the practical application to human life, present and to come, of the eternal principles of morality, which have ever sought the ennoblement, enhancement, and extension of life. The people called Eugenists are no more to be found among those who take this project and use it for any personal or partisan purpose than the people called Christians are to be found among those who use their religion for the advantage of their business, or their social position as a cloak for private vices or public plunder. One cannot here recount the arguments to show that Christianity and the other great religions of the world are definitely eugenic; let it suffice to assert the eugenic conviction that the Kingdom of Heaven may begin on earth only by recognising the sanctity of children, and admitting that "of such is the Kingdom of Heaven."

If the Eugenist makes these claims, as he does, without fear of challenge, then he is entitled to protest that eugenics should no more be used for mean or selfish purposes than should any other constituent of true morality or true religion. Eugenics accepts the words of Ruskin: "There is no wealth but life," and the motto of Watts: "The utmost for the highest." Those who do not assent with their whole nature and their unreserved conviction to these words, those who would qualify them in the interests of their own self or family, or class or sect, or clan or race, are not the people called Eugenists.

"FOR OF SUCH IS THE KINGDOM OF HEAVEN"

From the painting of "Golden Days," by Mr. Joseph Clark.

THE ONENESS OF ALL THINGS

The Mighty Scheme in which Stars and Continents and the House you Live in are held Together as one

A ROLLING UNITY OF STARS AND SUNS

We have now completed our preliminary survey of what, without having examined the meaning which the word conveys, we have agreed to call the Universe. We have put the earth in its place, and found it to be a member of the solar system, one of the company of worlds; and we have looked into the atom, and found it to be an atomic system, into the ultimate depths of which we cannot pierce, any more than into the ultimate depths of starry space. Having glanced thus without and within, we have obtained some idea of what we are about to study; but meanwhile we have been making the most gigantic assumptions, handling the most colossal ideas, without verifying or examining them. The idea of a universe is, in part, the idea of a company of worlds, worlds too far for the telescope, worlds too small for the microscope, but it is vastly more.

For instance, we have been calmly taking it for granted, hitherto, that our first study of the skies, and our first study of the inwardness of matter, both have to do with one and the same thing. In a word, we have assumed, without any attempt to define it or to prove it, the idea of the universe as a single whole. It is perhaps the greatest of all ideas. All science goes to prove it; all science makes progress by assuming it.

However free and original and critical our minds, we all run a risk of taking for granted the ideas and customs and institutions which we discover around us. The idea of the universe as a single whole is in this case at the present day. All who have looked into these questions at all find this idea accepted, established, unquestioned; so much so that they often accept it without really knowing they have done so. They speak of Nature and the Laws of Nature and the Universe in the same breath as that in which they refer to a "providential occurrence"; they study the week-end weather forecasts issued by the Meteorological Office on Saturday, and join in prayers for rain or fine weather on Sunday. Whatever the right and the wrong of this may be, certainly it requires examination; and repays it, as we shall instantly see.

What we call Nature or the Universe is doubtless "from everlasting," but our idea of it as such is a modern discovery, so modern that it has not yet come into its own. Modern science, after all, is only about three hundred years old—less than ten generations; and Greek and Arabic science was but the tiniest stream, though its source was authentic and pure. At the present hour ninety-nine people out of a hundred live in a medley of wild and ludicrous contradictions, so far as both their ideas and their conduct are concerned in this matter.

Consider for a moment only the variety of conduct and of underlying theory displayed by nearly everybody in the presence of illness or threatening death, and we see that "clear and distinct ideas," all perfectly compatible with one another, are far to seek. In such cases we contradict ourselves just as flagrantly as the man who gets wireless information of the approach of a cyclone from the Atlantic, and sends petitions to Heaven for a certain kind of weather. These absurdities do no harm to Truth, but they are liable to harm ourselves, and they do our reason little honour. We are not ready for science until we have examined our ideas and established our first principles; and this can best be done by simply comparing the two contrary ideas of things which are too often jumbled in our minds, though they are mortally opposed at every point, one being the assertion of science, and the other the denial of it.

The pre-scientific or superstitious idea of things regards them as a chaos, having no internal principle of order and unity. The scientific idea is that of a cosmos; and if one of these views be true the other is false.

The chaotic view has been the view of the overwhelming majority of all mankind since mankind ceased to be apekind, and it is the majority view, in some form or another, now. This chaotic or superstitious view does not regard the universe as a universe or Rolling Unity, which is the immensely significant meaning of the word, but as a Multiverse, a Rolling Many.

The Real Difference between the Wise Man and the Fool

Since it is, according to this view, not one, but many, its parts being, therefore, not parts of one another, and not interdependent, there is no certainty in the happenings we survey, and in the happenings of which we are the victims. That is not to say that superstition and ignorance go so far as to deny that things have causes. However ignorant or mad men may be, they never suggest that events happen uncaused. The difference between the savage or the lunatic or the fool and the man of science is in the kind of cause they believe in. The man of science says that things are a universe, a cosmos, a great whole which he calls Nature, and he declares that the causes which work the effects we witness, and all the effects which we do not witness, are in the nature of things. He declares, further, that Causation is universal, because the universe is all-of-a-piece; and he approves the fine lines of the poet—

> Thou canst not st r a flower
> Without troubling of a star.

To this view we shall return, and, having returned, shall never leave it for a page or a line to come—unless we there abandon science and are false to our task.

The Way in which the Savage Looks Out upon the World

But before we consider it, and show how modern discoveries, such as those we have already looked at, bear upon it, we must try to understand a little better the chaotic view of things which science has replaced.

For convenience, we may talk about "the savage." Our remarks may apply to the most fashionable and exquisite of modern ladies, visiting the palmist, the crystal-gazer, and the necromancer; nor is it our present business to ask what proportion of modern people are merely savages who have, so to say, adopted European clothes. The warning is necessary, since the accepted way of talking about "the savage mind" blinds us to some of the most staring facts of the "modern mind."

The savage, then, in his birthday suit or "faultless evening-dress," as the case may be, looks upon things as partly rational and orderly, but mainly directed and caused in quite another way. What he knows and sees and understands he regards as rational. He repeatedly notices that water wets and fire burns. Such happenings he accepts as orderly, and, indeed, makes as good a science as he can of them. In such cases we are all agreed everywhere.

But beyond such cases as these, where only one theory is possible, the savage thinks otherwise. Everything which is not straightforward and under his nose he looks upon as miraculous, and due to the wish of invisible beings. Thunder and lightning are the voice and bolt of angry Jupiter. The death of an infant—which has been fed on herring and pickles—is "the will of Providence." Disease is the punishment inflicted for failing to sacrifice to the gods, or to pay a high enough sum for the upkeep of their priests.

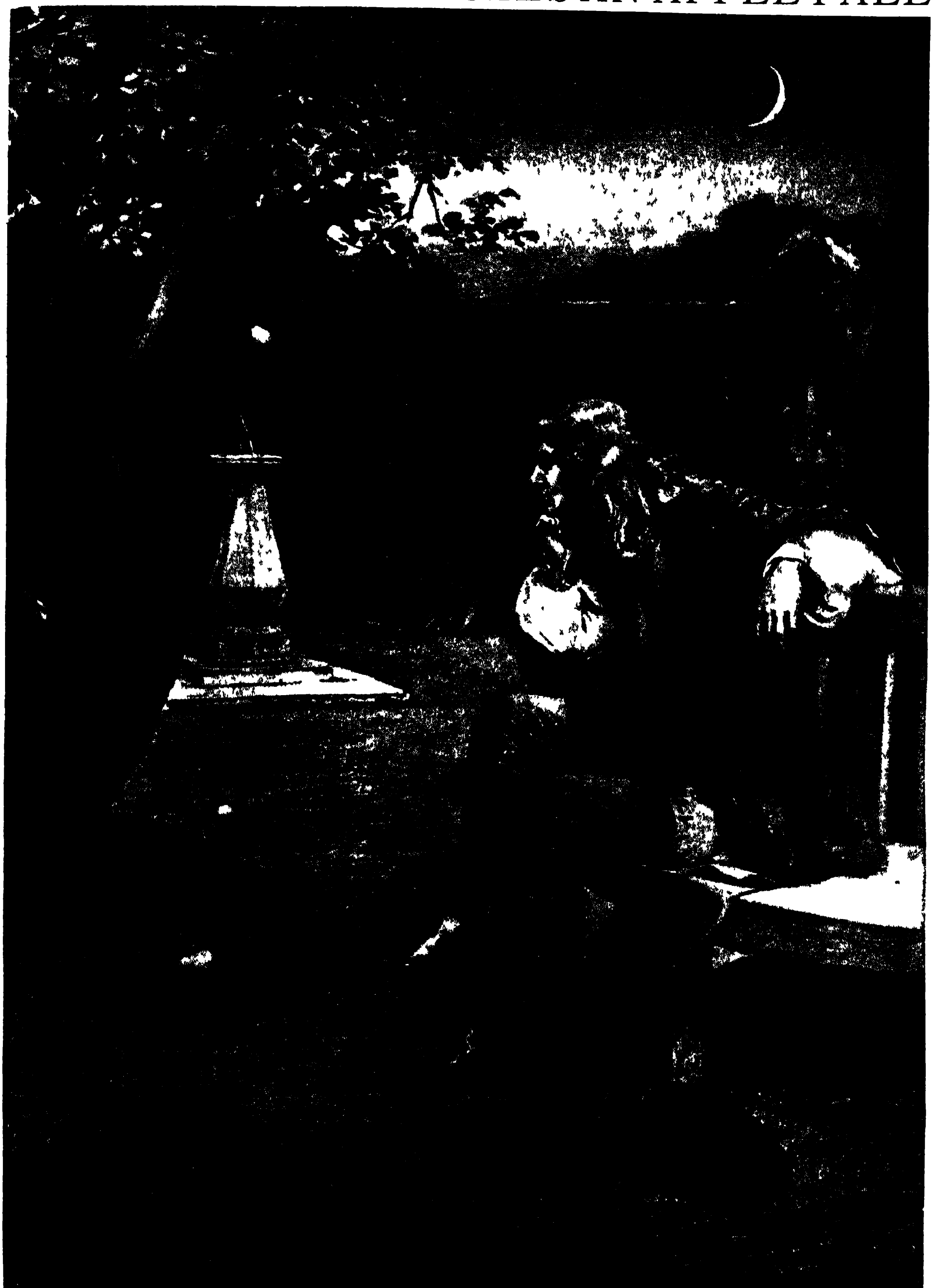
The Two Men for whom there is no Room in the World

According to such a view of life, an eclipse is due to a quarrel between the god of the sun and the god of darkness. An earthquake is due to a nightmare, and uneasy sleep of the old dragon who lives underneath us, and supports us. A child's sickness is due to the "evil eye," some white stranger having looked at it. You break your leg, and remember that someone who hated you cursed you, and wished that your bones might rot. The moon, Luna, causes lunacy; and the Sovereign Touch cures the King's Evil.

Instances are as numerous as mankind. They can be drawn from any age or people. Between this view of things, and that which says that the Universe is a universe, that all things are one, and that causation is constant, consistent, universal, there can be no compromise. The man who seeks to cure the King's Evil by taking the child to be touched by the king, and the man who proves that the disease is due to the child having drunk milk from a tuberculous cow, and says that milk containing the microbes of this disease must no longer be sold—these two men cannot agree to differ, and there is not room for both of them.

We must hold firmly and clearly by our view that the universe is a mighty, consistent whole, and that the only way in

SIR ISAAC NEWTON SEES AN APPLE FALL



One of the great days of the world was the day on which Sir Isaac Newton, sitting in his garden in Lincolnshire, noticed an apple fall to the ground, and asked himself why it fell. It was the realisation of the tremendous law of gravitation, by which all things are held in place, every particle of matter in the universe attracting every other particle with never-failing, never-varying force.

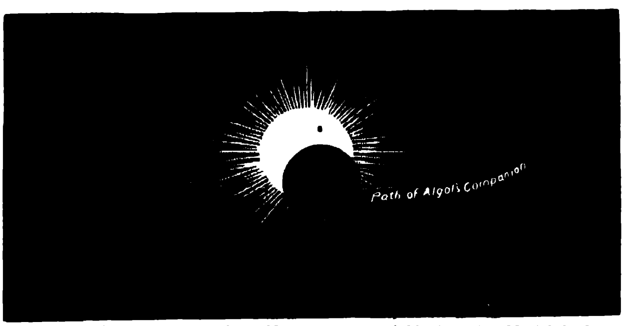
which we can control material events is by learning those conditions of their causation which we call the laws of Nature, and acting through those laws. And we shall have a poor understanding of those laws, or of the least of them, if we do not soon perceive, and for ever remember, that if these laws are indeed natural they are *therefore* Divine. So much was necessary if our study of the world was to be much higher in the scale of reason than a puppy's study of the pattern and colours of a carpet.

And now let us survey the evidence which teaches that this magic carpet we call the universe was woven by one Maker, and is a perfect and single whole, notwithstanding the number of its threads, and their variety of direction and colour.

Consider, first, the company of worlds. What evidence have we that they are a company, in the full sense of the word? Why should we not suppose that they are all inter-dependent? What evidence is there that they form parts of a whole? We see no bond between them, no chains or ropes, and we do see that they move in all manner of directions, at all manner of speeds.

There are friends who rule and are ruled by one another, who cannot distinguish between their own wishes and each other's, and who are a million times closer bound than any bond of flesh could hold the Siamese Twins. Just so we learn that the stars and planets, having no material bond, are yet bound together, and influence each other's form and structure and movement, without one moment's intermission throughout all the ages of their existence.

"Stars and planets," we said, but that feebly expresses the truth. Newton declared that every particle of matter in the universe attracts every other particle with a certain constant, never-failing, never-varying force, which we call gravity. The couplet about the flower and the star is therefore literally true. Stars, planets, moons, comets, shooting-stars, rock, water, air, all forms of matter everywhere, are bound together, each atom to all other atoms, and all atoms to each, in a bond which utterly defies every attempt to modify it in any direction or degree. On this one ground alone, having regard to all the evidence we can obtain—not a mean quantity to-day—we are entitled to say that the universe *is* a universe. Newton saw an apple fall, and argued thence that the moon must similarly tend to fall to the earth, and thence that the earth must similarly tend to fall to the sun. When at last he was satisfied that his law included the whole solar system, our sun and its planets, he went beyond the evidence, and declared that all matter everywhere attracts all other matter. He had no right to do so but one: the right given him by his faith that the universe is one, and that what is true of the sun must be true of every star.



WEIGHING A STAR THAT HAS NEVER BEEN SEEN

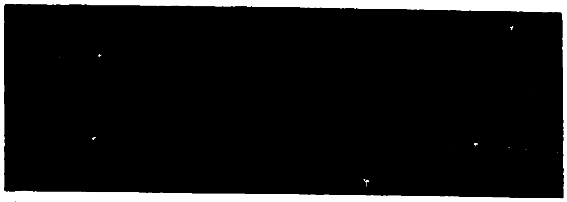
The law of gravitation, by which all things are held together, has enabled men to prove the existence of a star that no eye has ever seen. The light of the fixed star Algol diminishes every few days, and this is now known to be due to an eclipse of the star by a companion which has never been seen, though it has been weighed and measured and its place is actually known.

Only long after Newton's day was it possible to obtain evidence that the law of universal gravitation is what it asserts. Auguste Comte had, indeed, declared that by no possibility could men ever ascertain whether, at the inconceivable distance of the stars, gravitation is at work. Nevertheless, the evidence has been forthcoming; and astronomers have been able not merely to find the evidence, but, by observing and measuring the disturbances in the motion of a bright star, to prove the existence and compute the mass and the distance of a dark star, never to be seen by the eye, but yet known, weighed, and placed by its gravitational action on its bright neighbour.

The case of the star Algol is a good example. Algol is the Arabic name for Demon, given to this star because the Arab astronomers could not account for its variations. The spectroscope has now proved the existence of a companion star which eclipses Algol in two days twenty hours forty minutes and fifty-three seconds. The diameter of Algol is believed to be about 1,120,000 miles—one-third larger than our sun, and the diameter of Algol's companion, the dark star, is estimated at 840,000 miles, or nearly as large as our sun. Although this body has never been seen by mortal eye at this inconceivable

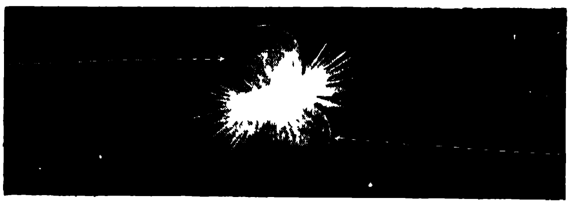
distance, its existence is undoubted, and we owe the discovery to the law of gravitation.

That is satisfactory from the point of view of those who seek to prove that the universe is a universe, and that its laws are verily uniform and universal. But just within recent years the twentieth century has succeeded in obtaining evidence of action in the sky which renders the universal character of gravitation far more important still, and which we can only hope to understand by looking at it in the light of gravitation. Our business here is only to quote the outlines of the new discovery, and they may be easily set down. We find that the "fixed stars," so called, are all in motion, and that their motion is orderly. It varies in direction in each case, but on the whole its motion, so far as the stars we can observe are concerned, is mainly in two opposite directions. J. C. Kapteyn of Göttingen and A. S. Eddington of Greenwich have demonstrated the existence of these two streams —which a famous astronomer, by a most illegitimate and unscientific use of the word, has lately called "two universes." They are not two universes, but two halves, or parts of the Universe. As they flow through and pass each other, members of the two streams may imaginably collide. Such collisions would have tremendous consequences, and may be the key to the history of individual stars—their making and heating, and cooling and destruction. All this we must later study. Meanwhile we note the enormous importance of gravitation among the stars.

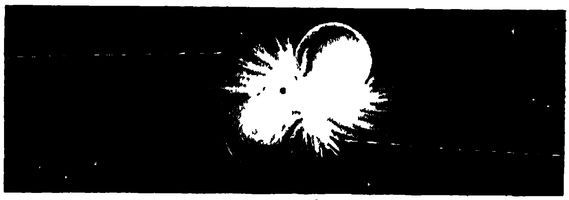


TWO DARK SUNS APPROACHING ONE ANOTHER

THE SUNS ABOUT TO COLLIDE

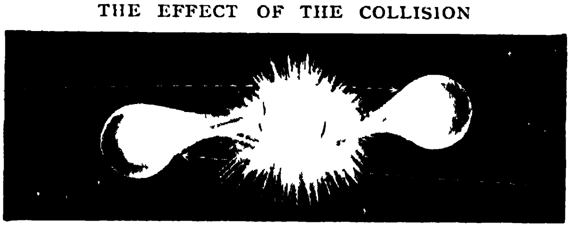


THE TWO SUNS IN COLLISION



THE SUNS "GRAZE" AND PASS ON

THE EFFECT OF THE COLLISION



A NEW FIERY WORLD EMERGES

THE NEW STAR SHINING IN THE HEAVENS

These drawings illustrate Professor Bickerton's theory of the birth of new stars. It is believed that stars occasionally collide, each leaving behind a portion "grazed" off in the collision. This may become a new star, shining for a time in the heavens before its light dies out

Mathematicians have calculated the chances of collisions between stars moving at random, or in opposite streams, but when their reckoning is made they have to remake it, since each and all of these stars are attracting each other. There are many collisions in London streets every day, when drivers seek to avoid and thus repel each other: how many would there be if they attracted each other? It is evident, therefore, that if we are to allot to stellar collisions a place of supreme importance in the making of stars, and ever new stars, throughout the ages, we must increase our respect for the law of gravitation, which must immensely multiply the number of such collisions; and we shall be prepared to discover that this

law, working everywhere, is not only one of the proofs of the Universe, but one of its never-weary architectural forces, making and remaking it from age to age.

Let it not be supposed that only gravitation justifies us in looking upon the stars as parts of a mighty whole. On the contrary, our study of light and heat waves teaches us that here also are forces and laws whose action is universal, and reacts between star and star. Within the last few years it has been proved, for instance, that a force called radiation-pressure acts everywhere and brings into relation all parts of the Universe. But this discovery about light and other kinds of radiation is insignificant compared with other evidence which sunlight and starlight afford that the Universe is one.

This evidence, also, can only be outlined here, but it corresponds as perfectly to the inward survey made in our second chapter as the evidence of gravitation corresponds to the outward survey we made in our first. When we looked as far as we could into the inwardness of things we soon encountered something called—though we now know it should not be called—the atom. Atoms, we learnt, are of some eighty-four kinds, each kind making up one of the elements, such as carbon or hydrogen or sodium. We learnt, further, that the internal structure of these atoms is composed of moving units, called electrons.

Flower in the crannied wall,
I pluck you out of the crannies,
I hold you here, root and all, in my hand,
Little flower—but *if* I could understand
What you are, root and all, and all in all,
I should know what God and man is.

It has long been known that when any element is heated enough to give out light, that light is peculiar to the element in question, so that any element can be recognised or detected by the light it gives, no matter what distance the light has traversed. It has only just been understood that the character of the light given out by any atom depends on the number and movement of the electrons in it. But now we can appreciate one of the most wonderful of all proofs that the Universe is really one—the proof that it is throughout constructed of the very same materials.

A little common salt, made luminous, as by holding in a flame a wire that has been touching it, gives forth a yellow light. This light can be precisely described, measured, and analysed; and it is the characteristic light of sodium, the metal which goes to make up common salt. No sooner do we attempt to analyse the light of the sun in the same way than we find that it is partly made up of the same arrangement of light-rays as we know to be characteristic of sodium. We are much more certain that sodium atoms, whose light-autograph we know so well, are in the sun as well as in common salt than anyone can be that a signature before him was written by the man whose name it spells. The handwriting expert may be deceived, but there is no forgery in the skies, and the signatures of the atoms are unmistakable. We know that there are sodium atoms in the sun, for we have only to decipher sunlight closely in order to read their names.

The application of this principle speedily shows that the elements we have identified on the earth are the universal elements which compose, in varying proportions and combinations, all heavenly bodies as well. To mention only the most recent instances, the peculiar element helium, found in the sun, by its characteristic contribution to sunlight, was later found in an earthly mineral called cleveite, and later still was proved to be one of the elements produced by the breaking up of the element called radium.

This last sentence reads like a contradiction in terms, and it is indeed in need of explanation. The key to it adds incalculably to our idea of the oneness of things, and it is yet another of the achievements of

our century. We have already learnt that atoms are not really atoms, but have parts, and therefore that the elements of which they are the units are not really elementary. We have discovered that every atom consists of units, called electrons, arranged in certain orderly ways or in a kind of atomic system, which has its own centre of attraction, comparable to the sun and the solar system. The great fact which has now to be stated, and which may be said to surpass anything hitherto known as proof of the oneness of things, is that all electrons are the same, no matter where we observe them. All the electrons in a given atom are the same. They are one and the same in all atoms of a given element. They are the same in atoms of different elements. They are the same in atoms observed on different worlds.

Hitherto, somebody might have said, and many people did say, we had not found any one material which makes up all things, so proving that all things are one. On the contrary, we have found not one but about eighty different materials which we called elements, of which we asserted that they could never change into one another, though ignorant men, we said, used to look for a "Philosopher's Stone" which should turn lead into gold. Our assertions seemed accurate, but they by no means confirmed the idea of a universe, for a universe ought to be made of some one ultimate stuff, and not eighty different stuffs.

Radium, the revealer, and the work which it has suggested and guided, have shown that the elements are really compounds of simpler units, called electrons, and that these electrons are all everywhere the same. We have, therefore, all but reached the proof in demonstrable form that there is a simple stuff of which all things are made.

Chemistry and physics, and philosophy too, have long sought for this primitive, simple raw material of all things, and men have often thought that it was found. But this new discovery makes a new age in the history of human knowledge, by showing us the "one element" of which all material things are made. That element itself may prove to be not matter at all, but a form of electricity, and we may find, as we do, that matter dissolves under our analysis, and leads us to a beyond which we cannot grasp; but the fact remains that we have at last succeeded in tracing and tracking the new universal *something* out of which is made all the so-called elements, and all their millions of compounds, which compose the material universe. However much farther the journey be, and even though it should be endless, this is a great step into the heart of things.

THE MARVELLOUS ENERGY THAT WILL BURN THROUGH ICE AFTER COMING 90 000 000 MILES

The sun is the most astounding manifestation of energy in the universe. Its heat rays, after a journey of ninety million miles, reach earth with their energy unspent, hot enough to light a fire if directed through a piece of ice rounded like a magnifying-glass.

It is possible to go even farther, and to recognise two *somethings*, not easy to describe or define, which are yet "universal things," and undoubtedly real. With the survey of these we may consider that our idea of the Universe is adequate; and we may therefore go ahead with the detailed scientific study of what the Universe is, and what it does. But these two things must be named first, and we must have some notion of what they mean. Without them, we cannot attempt to study universal

evolution, nor a single movement or action on the earth or in the sky.

Ether is the name of one of these things: the "ether of space," it is often called. Its existence has often been denied, notably by the late Marquis of Salisbury on a celebrated occasion. That, however, was in the nineteenth century; and the twentieth century finds no one, however confident and ill-informed, to question that the ether, whatever it is, is a reality, and a universal one.

The Great Vehicle of Electricity and Light and Gravitation and Heat

As modern science understands it, it is absolutely and continuously everywhere, and is the vehicle of the great forces and activities of electricity, gravitation, light, and heat, which mould and move the worlds. What it is "in itself" we do not know, but we strongly suspect that, impalpable though it be, it is far more real than matter. If it be the necessary vehicle of electricity and of gravitation—which is suspected by the leaders of modern physics to be electrical in origin and nature—and if gravitation acts between all portions of matter everywhere, and matter is itself electrical—then plainly we can never escape from the ether, whatever part or aspect of the universe we study; and its existence is one more overwhelming piece of evidence of the oneness of things. Contradictions, as they seem to us, and mysteries at present insoluble, the ether presents to our study, as we shall later see, but our business is to face difficulties, and believe that they are worth solving.

Energy is the name of the second of these two universal things, which we must name now because they contribute so powerfully to the idea of the universe as one.

The Energy which is in Everything and Travels Everywhere

Energy is a comparatively new word in science, and its introduction and definition, chiefly by British students of Nature, was a great service to modern thought. It is yet another of those real things which cannot be seen and handled. We can define it only by its properties, by what it does; and this power to *do* is just what makes it. A great writer has expressed the view that the chief service of the last century to what is called "exact science" was its discovery of energy as a universal thing, and of the wonderful properties which it possesses, finally leading up to the magnificent conception of the Conservation of Energy, which we must proceed to study in our next chapter.

Here we are concerned with energy because it is a universal thing, and because its behaviour proves the oneness of things more abundantly than any evidence we have yet mentioned. Most householders are now familiar with the term "units of electrical energy," and they realise that there is a measurable kind of power which they can turn into light and heat when they like, and that this electrical energy can also be turned into the energy of motion in the case of trams and trains. Here is an invisible something, which is certainly real—the energy of the moving tramcar which hits you is no myth, though you cannot hit it back—and which can do all sorts of things and travel all manner of distances. The energy of sunlight, having travelled many millions of miles, can raise a blister on your cheek as readily as the energy stored in water may raise a hydraulic lift, or the energy of petrol may raise an aeroplane or drive a motor-car.

The Energy of the Sun which Enables us to See the Sun

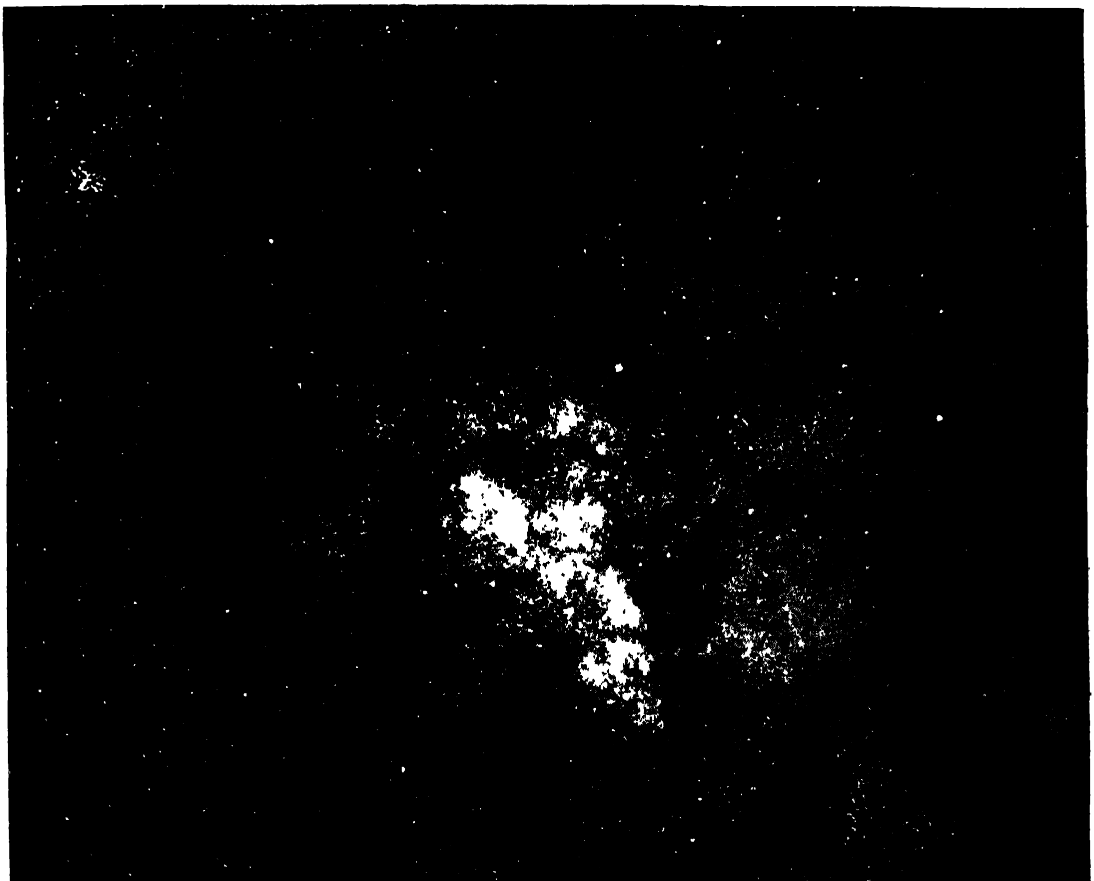
Here is an invisible, real something which does things; and when we study it we shall find that it has definite laws, never transgressed, not even by radium, as so many people supposed a few years ago; and we shall find, too, that its doings are universal, and that its powers can be transferred from any part of the universe to any other. Every star we see is sending energy to the earth; we could not see it but for the action of its light-energy upon the pigment in our eyes. That energy may have travelled many billions of miles before it reached our eyes, and may have taken thousands of years to come, but it is essentially the same thing as the light-energy of a match which we strike at arm's length.

What is true of light-energy, the form of energy we call light, is true of electrical or heat energy, the forms we call electricity and heat. It is true of the energy contained in all forms of motion, and the energy produced when we burn coal or explode petrol. In all these, and in all other cases where anything happens in the universe—and something is always happening everywhere—energy is at work, and energy is really one and the same thing everywhere. The evidence is already sufficient to show that we are compelled to think of all things as one, to think of the universe as indeed a universe; but we shall find this a thousand times clearer still when we study the law of the conservation or persistence

of energy, which is the chief factor of all change, yet is changeless in itself.

We have spent only a few pages on a theme which has occupied the greatest of thinkers and writers for centuries past, but we have seen enough to be convinced that, as Indian philosophy declared, not centuries, but thousands of years ago, the Real is One. This is not only a great result of science or knowledge, but it is the promise and the guide of future knowledge. If things are really one, every fact has in it, if we knew enough, the key to all other facts. That may sound extravagant, but it is the sober truth that the study of what happens in a vacuum tube may give us the key to the history of the stars, and that the observation of a falling apple may lead to our learning how the heavens are balanced, and what their destiny may be. Lastly, we must realise that, if all things are one, we cannot discover anything that is outside the universe.

In other sections we study such things as life and man and plants and nations and manufactures. All these things are part of the universe, and subject to its laws. Gravitation is at work between the stuff of this paper and the stuff of the reader's eyes, and the stuff of the sun and the stuff of Halley's comet. All these things, and all other things, are bound by that link; and if all these could be dissolved into their units we should find identical electrons composing them all, sun and paper, eyes and comet. All these things have energy, and are themselves acted upon by the energy outside them; and if science is not being utterly misled by all the evidence before it, that energy was from everlasting and will be to everlasting, unchangeable, yet never the same, working in stars and men and microbes, in martyrs and apostates; inexhaustible, unweary through infinite ages past as it is to-day, and as it will be in infinite ages to come, thus making the universe not only one in Space, but also one in Time.



THE MIGHTY STREAMS OF STARS WHICH ARE FOR EVER MOVING THROUGH SPACE

The early years of the twentieth century have made an important addition to our knowledge of the stars, which we now know to move in an orderly system, held in place by the same law of gravitation which holds in place the earth and all that is in it. As they flow in two opposite streams, stars may imaginably collide, and it is possible that out of these collisions new stars may emerge.

THE HILLS FLUNG UP FROM THE SEA

As we look upon this photograph of the Himalayas, it is incredible, though we know it is true, that these mighty heights were "flung up" from the sea. The crumpling up of the earth as it shrank in cooling had the effect of forcing up great masses; and so, in the depths of a sea which has now disappeared, the Himalayas were formed before a single man was on the earth.

THE EARTH'S UPS & DOWNS

The Great Upheaval in which Mountains Rose out of the Sea and the Ocean Depths were Formed

SOWING THE DUST OF CONTINENTS TO BE

We have seen that the earth cooled down till it formed a permanent crust, but it must not for a moment be imagined that the primeval crust has persisted unchanged till modern days. The original crust was hot, still in process of cooling, still wrinkling and puckering, still splintering and spluttering, still grinding and griding, still heaving and subsiding. It was also a dry crust, and a hard crust, and it must have taken ages to brim the ocean beds and emboss the continents. Between the first little steaming puddle and the Pacific Ocean, between the first little lava island and the summit of Mount Everest, must have been many æons and many agonies.

By what stages earth attained its present contour and its present disposition of land and water we can only surmise.

According to one very interesting theory, the earth, as soon as it had tossed away the moon, reassumed a pear shape, and round the neck of the pear gathered the first great sea. The big end of the pear would thus be a great continent, and the small end of the pear would emerge as a small continent in the middle of a great sea—the primeval Pacific Ocean. There would thus be a land hemisphere and an ocean hemisphere. The land hemisphere is supposed to have afterwards collapsed in places, forming the Atlantic, Mediterranean, and Indian Oceans, and there is a good deal of independent evidence to show that these seas were originally dry land.

Even now we find signs of this primitive division into land and sea hemispheres, for it is still possible to divide the globe into two hemispheres, the one containing almost all the great continental masses—Europe, Africa, North America, most of South America, and most of Asia—and the other containing comparatively little land—Australasia, New Zealand, a bit of South America, and a bit of the Malay Peninsula.

In the earliest geological times it is probable that a shallow sea spread over almost the whole face of the globe, and that the dry land consisted simply of groups of great and small islands. In those days Africa was probably represented by a few scattered islands not much bigger than Madagascar, and India by an island not much bigger than Ceylon, and America by a few islands not much bigger, taken together, than Australia, while only a corner of England was visible. By degrees, however, as the crust contracted, the ocean beds deepened, and the land areas increased, and sea and land established permanent spheres of influence, so to speak.

All great upward changes in the contour of the earth's crust have been due to the crumpling action of contraction. The earth's crust is not homogeneous in composition; and when it cooled it solidified unequally, and when it contracted it contracted unequally. Professor G. A. Daubrée illustrated the principle of the contraction of the earth by means of a child's balloon. To the outside of such balloons he applied partial coatings of adhesive paint, laid on in various patterns. He then allowed some of the air to escape, and found that the balloon contracted irregularly. Those portions stiffened by paint contracted less than those unstiffened, and rose like islands traversed by wrinkles above the general surface. In some such way the unequal contraction of the unequally stiffened crust of the earth may have produced the inequalities of its surface—the mountains and ocean beds.

Even after the present continental and ocean areas were fixed the land must have continued to rise and fall in a see-saw fashion, so that at one time one bit was

up and then another bit; and geological evidence shows that almost the whole land surface has been submerged at some time. The cause of the upheavals is mainly the contraction of the earth's crust; the cause of the subsidences is mainly the wearing away of the land by rain and rivers. But we shall return to this subject later on, when we come to speak at greater length of mountains and the way in which they are made.

In early days there were tremendous upheavals of deposits from the bottom of the sea, and these were gradually worn away by the action of rivers and rains, nd deposited as mud a d débris on the sea-floor again. In the so-called Proterozoic Age of the North American continent there were three great sedimentary upheavals from the floor of the sea, and sedimentary accumulations 18,000 feet, 14,000 feet, and 50,000 feet deep were successively raised into mountains. After each upheaval followed æons of wear and tear, and the great mountain ranges were gradually washed away. The Appalachian Mountains were lifted from a trough of mud 40,000 feet deep; and who can say how deep was the sediment that filled the floor of the ancient Tethys Sea, and was elevated into the Himalaya Mountains?

The Hills are Shadows, and they Flow From Form to Form, and Nothing Stands

The Cambrian rocks of Wales were once rocks in a vanished land that must formerly have filled the greater part of the North Atlantic Ocean. The land melted away into ocean mud; the ocean mud rose in time as the Cambrian rocks.

Mud, mountains; mountains, mud--that seems to be the rhythm of Nature. And Mother Earth seems to amuse herself making mud-pies and washing them away again. It may be difficult to believe that massive rocky mountain ranges can be washed off the face of the earth in this way, yet washed off the face of the earth they certainly are; and modern estimates of the work done by rivers prove that the process, geologically speaking, is not a very slow one. The Mississippi lowers its basin one foot in 6000 years; the Rhone lowers its basin one foot in 1528 years; the Pc lowers its basin one foot in 729 years. Taking an average rate of one foot in 3000 years, Europe would be worn down to sea-level in three million years; and in ten million years, provided that there were no upheavals in the meantime to raise the sediment, all the other continents that are now visible on the earth would be under water. Thus do rivers

> Draw down Aconian hills, and sow
> The dust of continents to be.

Proofs of the up and down of land areas are innumerable. Almost all dry land we know once formed an ocean bed. London is built on clay, which contains remains of marine shell-fish, such as the nautilus, and which must have been originally deposited und r the sea as mud. Below the clay s cha k, which contains multitudes of such marine remains.

Have the Beds of Mid-Ocean Been Lifted Up and Down?

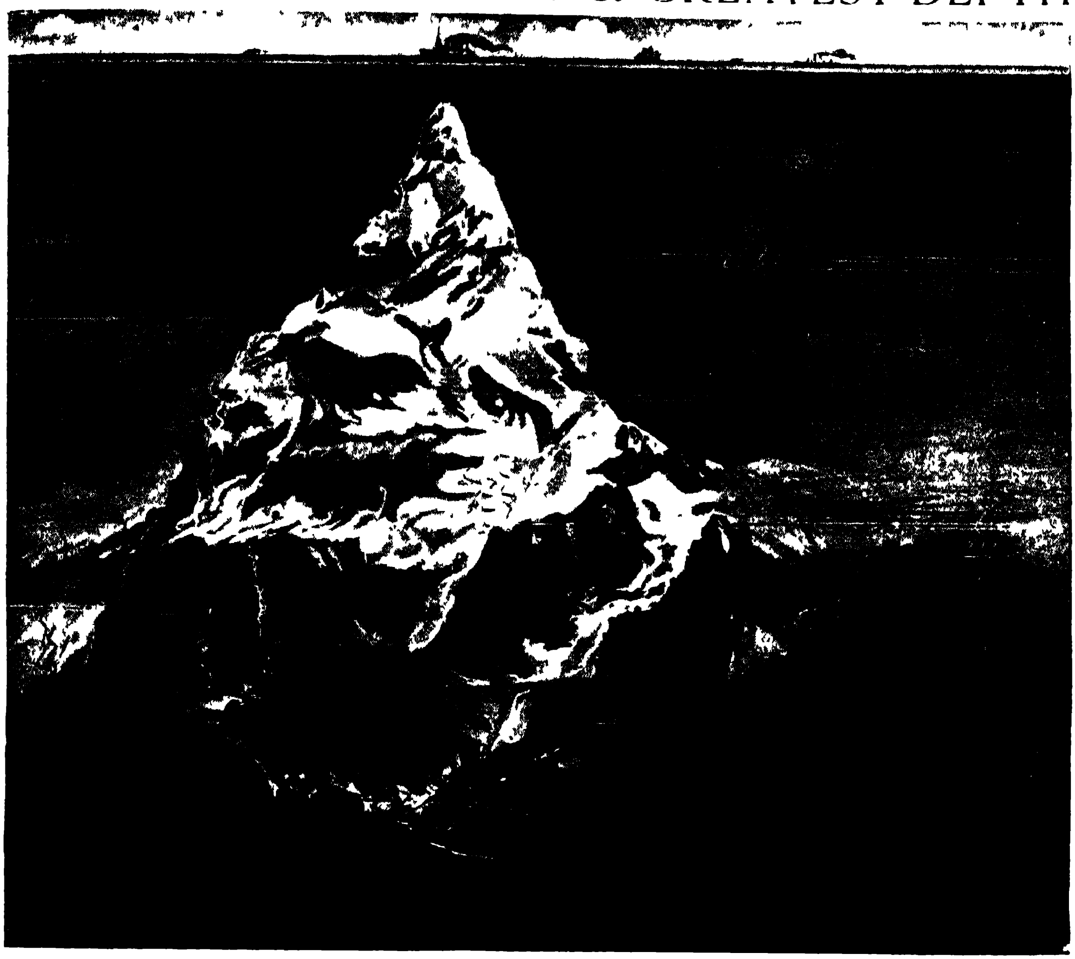
In the rocks of the Barton Cliffs, on the Hampshire coast, there are found within a distance of only a few miles over a thousand distinct species of the fossilised shells of molluscs, radiates, and other marine animals. Everywhere, in fact, remains of marine animals are found—on the Alps at 8,000 feet, on the Andes at 14,000 feet, on the Himalayas at 16,000 feet.

Whether the great basins of mid-oceans have likewise moved up and down is a moot question. On the one hand, we find that sediment from the land flows into the great seas for only a limited distance—a hundred miles or less—and that all the sedimentary rocks we know are made of such sediment, do not show special characters of deep-sea oozes, nor the sharks' teeth and whales' earbones, which are always found in the abyssal depths: also we find that the amount of salt in the sea tallies with the amount that the known sediments would provide, and gives no indication of unknown sediments from vanished oceanic continents, so that if ever there were continents in mid-ocean they were certainly not washed away.

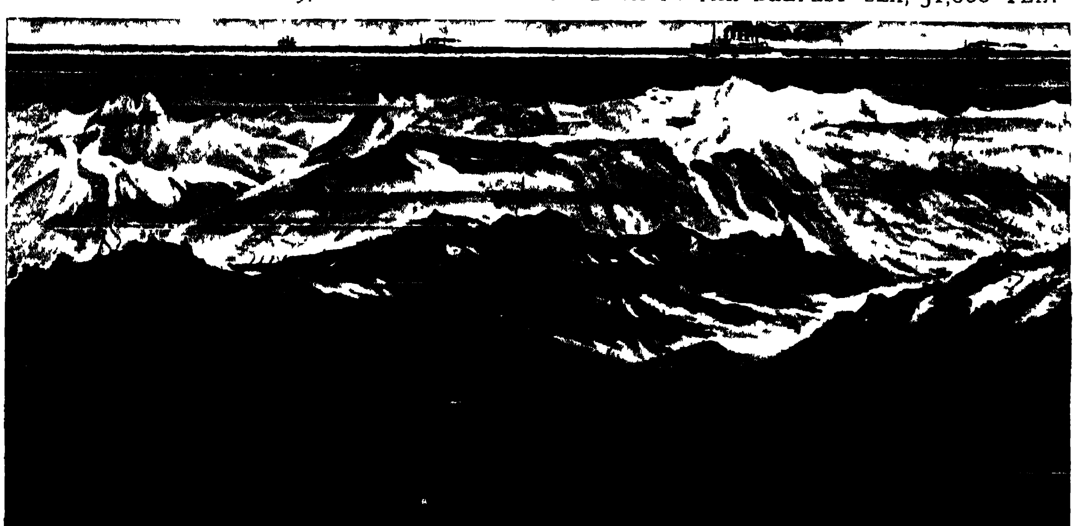
The Highways of Continents that have Disappeared Beneath the Sea

On the other hand, the distribution of plant and animal life suggests that certain islands and continents now separated by deep sea were once continuous. Arguing from the similarity of animal life, some authorities maintain that India and South Africa, Madagascar and the Seychelles Islands, were once continuous across the Indian Ocean, and that the land was broken up into islands, some of which are still marked by the coral atolls of the Laccadives, Maldives, and Chagos Archipelagoes, and by the Saya de Malha Bank. And there are similar indications that New Zealand, Australia, and South America were also continuous within the time of man. On the whole, it seems

THE GREATEST HEIGHT & GREATEST DEPTH



HOW MOUNT EVEREST 29,000 FEET HIGH WOULD LOOK IN THE DEEPEST SEA, 31,000 FEET

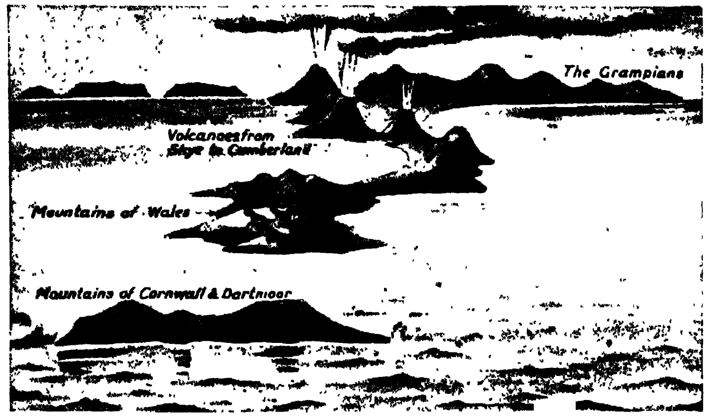


HOW THE LUSITANIA MIGHT SAIL OVER THE ALPS IF THEY WERE SET IN THE ATLANTIC OCEAN

The land is not so high as the sea is deep. The average depth of the sea is 14,640 feet; and if the highest mountain were set in the deepest sea it would sink out of sight as shown here. If the Alps were set in a particular part of the Atlantic, the Lusitania might pass over them on its way to New York.

probable that "continents indicate regions over which land has dominated since very early days, and that the profounder depths of the ocean basins mark the centre of larger areas, which have been even more persistently submerged."

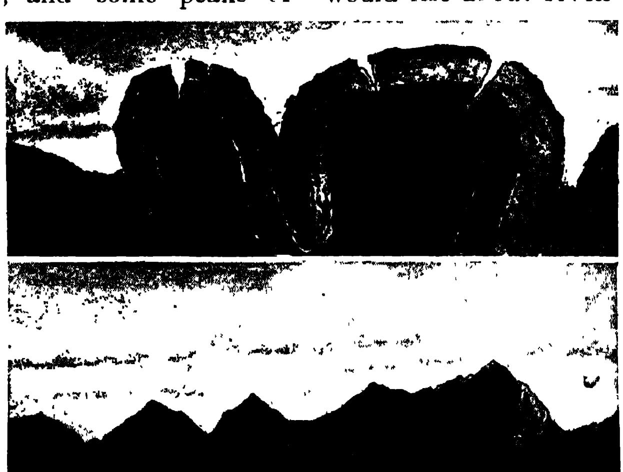
Leaving now the question of the fashioning of the earth's crust, let us look for a moment at the finished product.



THE BRITISH ISLES "IN THE BEGINNING"

In the early days of the world a shallow sea probably spread over almost the whole surface of the globe, leaving only groups of islands emerging as dry land. Only such corners of the British Isles as are seen here would be seen in such a sea.

We find that now three-tenths of the earth is dry land, and seven-tenths water. The greater portion of the land occurs in the great masses known as the continents of Asia, Africa, North America, South America, Europe, and Australia. The average height of the continental land is about 2100 feet, but Mount Everest towers 29,000 feet, and some peaks of the Andes reach over 22,000 feet. But the land is not so high as the sea is deep. The average depth of the sea is 14,640 feet, and its greatest depth about 31,000 feet. If we were to plant Matterhorns here and there in the deep seas, in most places they would just appear above the surface; and if we were to plant Mount Everest in the deepest spot, it would sink far out of sight. And the irregularities of the earth's surface are really very small.



THE MAKING OF THE ALPINE PEAKS

These pictures suggest the way in which the great Alpine peaks have been made. The crumpling up of the earth would thrust up great heights of rocks, and the influence of the wind and rain and sun would wear away the softer rocks faster than the harder parts. We know from the position of certain layers that some of the great peaks which fascinate climbers must have been weathered into shape in this way.

Big as the mountains are, and deep as the sea seems, it must never be forgotten that, compared with the huge bulk of the earth, they are little more than slight reliefs. A wet apple will have more water in proportion to its size than the earth carries in proportion to its size; and a midge on an apple would represent the size of the Himalayas on the surface of the world.

Professor T. G. Bonney supposes a globe of about the radius of the dome of St. Paul's Cathedral made to represent the earth. On this scale, correctly proportioned, "the peak of Mount Blanc would rise less than half an inch above the original level, the summit of Mount Everest itself would not be quite nine-tenths of an inch above it, and the ocean would be lodged in a shallow depression, much of which would vary from half an inch to an inch in depth." On a globe two feet in diameter, Mount Everest, made to scale, would rise about seventeen-thousandths of an inch, and a scratch three-hundredths of an inch deep would represent the depth of the deepest sea.

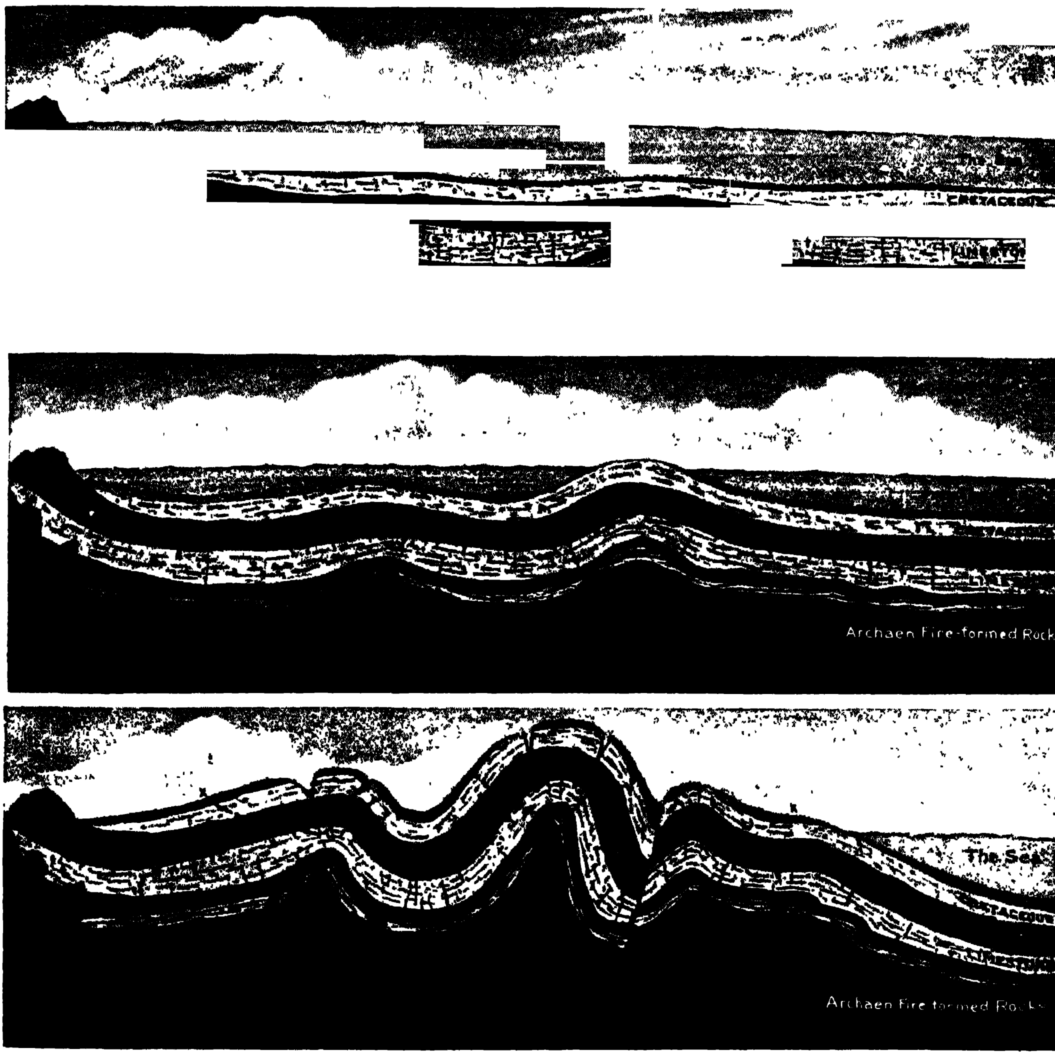
There is a story told of a Scotsman who argued that Scotland would be bigger than England if it were rolled out flat; but mountains are very deceptive things, and perhaps the Scotsman was over-sanguine. Even the Alps rolled out flat would only extend the Swiss frontier about seventy miles; and if, instead of being rolled flat, they were spread equally over Europe they would increase the average elevation of the continent by only 22 feet.

To such contours, then—continents and seas, plains and mountains—has the earth

been fashioned. Let us now see of what kind of stuff its crust is made, and how the stuff is laid on.

Altogether, about eighty chemical elements are found in the crust of the earth, but only sixteen are found in great quantities. The favoured sixteen are these: oxygen, silicon, carbon, sulphur, hydrogen, chlorine, phosphorus, fluorine, aluminium, calcium, magnesium, potassium, sodium, iron, manganese, barium. These elements make up ninety-nine hundredths of the earth's crust; other elements, such as gold and silver, and zinc and tin, and iodine forming the remaining hundredth. Let us look at some of the more important elements.

Of all the elements, oxygen is the most abundant; it forms about 23 per cent. by weight of the air, about 89 per cent. of water, and about 47 per cent. of the rocks in the crust. At ordinary temperatures, in its free condition, it is, of course, a gas—the gas that causes combustion and is essential to the phenomena of life. In the earth's crust it is found in combination with other elements forming solids.



WHY SHELLS MADE ON THE BED OF THE SEA ARE FOUND ON THE HEIGHTS OF THE ALPS

These three pictures represent an ideal section through the Alps, simplified to show how the mountains arose from the bed of the sea and acquired their present characteristics. The top strip shows a series of layers of sedimentary rocks beneath the sea; the middle picture shows the gradual rise throughout the ages; and the bottom picture shows the bending and doubling of the rocks through the contraction of the earth, as well as the effects of weathering, which has worn away parts, indicated by the dotted line. This emergence of the mountains from the sea explains why we find sea-shells on the Alps.

The element next in abundance is silicon, which forms about 25 per cent. of the earth's crust. Combined with oxygen, it forms a mineral called silica, which forms about half of the known crust and serves to bind all the others together. It is seen best in the

form of quartz. Apart from the function it plays in world-building, it is of inestimable importance to man as the basis of glass. Without silicon, no glass; without glass, no microscopes, no telescopes, no spectroscopes; and without these wonderful instruments how little would man know of the world—of "the boundless inward of the atom, boundless outward of the whole"!

Next comes aluminium, forming eight per cent. of the crust. It occurs chiefly in union with silica, as the so-called aluminium silicates, and is found in many rocks and clays.

More interesting, however, than any of these is the remarkable substance carbon. In the form of carbon-dioxide gas, it forms 1-2500th part by weight of our atmosphere. In solid form we know it as charcoal, black-lead, and diamonds. In combination with hydrogen, oxygen, nitrogen, and sulphur, it forms coal. It is the fundamental element of organic life; without it the world would have neither plants nor animal life.

One other elemental constituent of the earth's crust may still be mentioned—calcium, or lime. Calcium comes naturally after carbon, for it is in association with carbon, as calcium carbonate, that it is chiefly found. As calcium carbonate, or limestone, it forms four per cent. of the earth's crust, and its occurrence in the earth's crust is of the greatest importance to life, as without it there would be neither bones nor fertile soils.

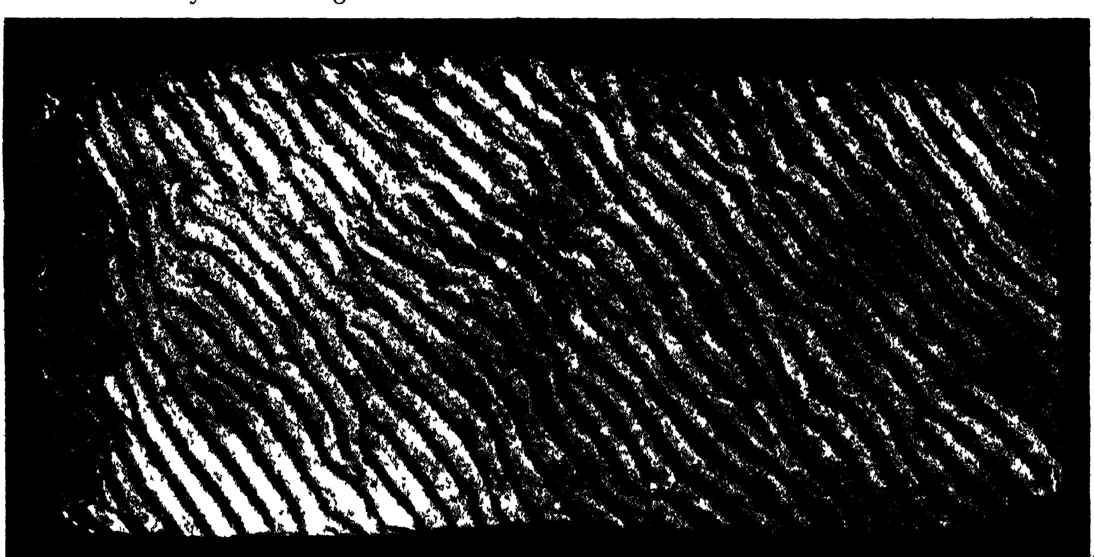
Such, then, are a few of the most important elemental constituents of the earth's crust. The very interesting fact has been pointed out that with one or two exceptions the elements essential for the construction of living protoplasm are just the elements most abundant in the crust, as seen from the following comparative table, according to the late Sir Joseph Prestwich.

Elements in Protoplasm in order of their abundance	Elements in the Earth in order of their quantity	Per cent.
1. Hydrogen	1. Oxygen ..	50·0
2. Carbon	2. Silicon ..	25·0
3. Oxygen	3. Aluminium	10·0
4. Nitrogen	4. Calcium ..	4·5
5. Sulphur	5. Magnesium	3·5
6. Iron	6. Sodium ..	2·0
7. Phosphorus	7. Potassium ..	1·6
8. Chlorine	8. Carbon ..	2·4
9. Sodium	9. Iron	
10. Potassium	10. Sulphur ..	
11. Calcium	11. Chlorine ..	
12. Magnesium	12. Other elements	1·0
		100

Within recent decades, the spectroscope has shown us that the sun contains almost all the elements that we find on the earth's crust. Geologically speaking, the earth's crust is composed of the elements we have named, compounded into hard material known as rock; and rock, in geological parlance, includes all the material of the crust, whether in massive pieces or in tiny particles. Granite is rock, but equally salt, soil, and sand are also rock.

According to their history and character, rocks are usually classified in two principal families—igneous, or eruptive rocks; and aqueous, or sedimentary rocks.

All rocks, in a sense, are igneous rocks, for all rocks were once in a molten condition;



RIPPLES OF THE SEA ON THE BEACH OF A MAN-LESS WORLD

Long before man came into the world the waves rippled over a beach of mud; the mud dried so hard in the sun that the marks of the waves were not washed out by the next tide; and, a new layer of sediment sealing them up, the marks of the ripples are preserved for us to-day, actual images of a world in which man had not yet emerged.

SUN-CRACKS IN THE EARTH ON THE BANKS OF THE COLORADO RIVER

This photograph affords an example which can be seen to-day of the way in which the surface of the earth is split up by natural forces. The picture represents a low plain on the banks of the Colorado River in California. In time of flood the river overflows into the plain, and leaves behind a rich deposit of alluvial mud, which is dried by the fierce sun, and cracked into immense blocks, leaving gaps from one to five inches wide, and twice as deep. Into these cracks the farmer throws his seed, reaping a rich harvest in a field irrigated, fertilised, and ploughed for him by natural forces.

but the term igneous, as a classifying term, is reserved for rocks which show signs of fusion; while the term aqueous is the term applied to rocks which have been broken up by wind, water, and frost, and strewn in layers on the surface of the earth. The term sedimentary is also applied to rocks formed by the deposit of substances in solution—as salt, for example and to rocks formed by the deposit of organic remains, as coal and chalk.

Igneous rocks are probably in most cases forced towards the surface by volcanic action. We find them intruded into sedimentary rocks and inserted between their strata; and from the condition of the surrounding sedimentary rocks they have evidently been intruded when at a very high temperature. When they escape at the surface they show as lavas and other volcanic rocks; but when they fail to reach the surface, and have to cool down under deep layers of sedimentary rocks, they acquire a crystalline character. Granite, for instance, is an igneous rock that cooled in the heart of sedimentary mountains, and is laid bare only after ages of wearing away.

Sedimentary rocks are in layers, as might be expected, since in the process of this formation layer is deposited on layer. If the layers are thin, they are known as "laminæ," and the rocks are said to be laminated. If the layers are thick, the layers are known as "strata," and the rocks are said to be stratified. Layers can be distinguished from each other only when there have been periodic changes in the size or character of the deposited material. A stratum may, of course, contain laminæ, and in such cases the strata may be compared to books laid one above another, and the laminæ to the leaves of the books. Sometimes it is very difficult to make out layers at all, and this condition obviously indicates a gentle and steady depositing; whereas strata distinctly differentiated indicate variable currents, with sediment varying in quantity and quality. As layers are usually deposited under water, it is not unusual, especially in the finer sandstones,

to find ripple-marks. In other cases, where the sediment has been exposed to air and sun, sun-cracks—such as one sees in sun-baked sand—are shown. In other cases, rain-marks, fin-marks, footprints of animals, and worm-tracks are visible.

Sedimentary rocks, as we have already seen, have been elevated from the floor of the sea by the pressure of the contracting crust. They are laid down in flat layers, but the pressure naturally disarranges and crumples, and may fracture them. They are almost inevitably displaced from the horizontal, and the degree of displacement is known as their dip. When the strata are torn the ends are apt to be displaced like the ends of bones in badly set fracture, and this displacement is known as a "fault."

The two opposing faces of a fault may be displaced to greater or less degree. Sometimes there is very great displacement. Thus, near Sedbergh, in Yorkshire, there is a fault estimated at 5000 feet, and there is a displacement in the Appalachian Mountains that has been estimated as no less than 20,000 feet. Great faults like these were probably produced by progressive displacement.

FOOTPRINTS ON THE SANDS OF TIME

These footprints mark the track of an animal that roamed the world before the days of men. They are the impressions of the foot of a prehistoric creature made in mud which dried up rapidly in the sun and were preserved in a layer of rock, a picture in the book of Nature which is slowly opening itself through the ages, before the eyes of men.

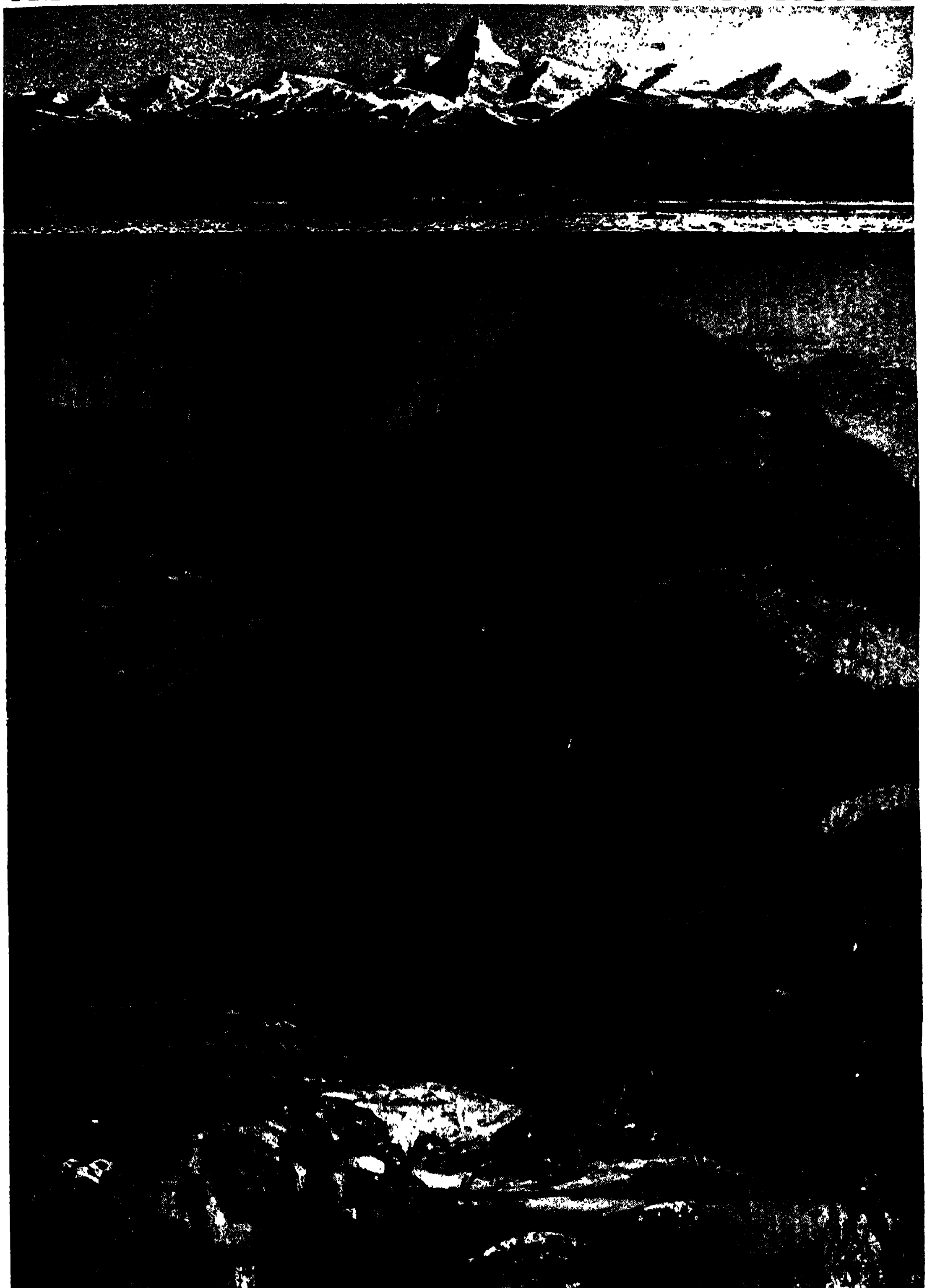
Strata are not only bent, tilted, fractured by lateral pressure, but they are also worn away by such natural agencies as frost, wind, rain, rivers; so that, instead of presenting a curved surface, they may present edges and angles. The edges of strata which appear at the surface are known as their outcrop or basset.

Both igneous and sedimentary rocks show splits called joints, which are caused by shrinking through loss of heat and water. In many cases hexagonal splits occur and hexagonal columns are formed, such as are well seen in Fingal's Cave, in Staffa, and in the Giant's Causeway, in Antrim. The splits take this hexagonal form simply because when "a mass is subjected to a uniform strain, the cracks, according to the law of least resistance, tend to assume a hexagonal form," or, as Bonney puts it, because "Nature, in producing an effect, avoids the mistake so common among fussy folk, and does not expend more energy than is necessary." Some rocks which have been deposited for a long time have been so changed in their structure by water, pressure, and heat that it is impossible to decide with certainty whether they are igneous or sedimentary, and rocks of this doubtful nature are generally termed metamorphic. Many such rocks have a foliated structure; that is, they show a peculiar parallel disposition of the minerals which compose them. Examples of metamorphic rock are seen in gneiss, mica-schist, serpentine, and statuary rock.

When we take a general view of the crust of the earth, nothing is more striking than the tremendous amount of sedimentary rocks that enter into its composition. Here and there are intrusions of igneous rock, but everywhere are tremendous sedimentary deposits — deposits which attain a maximum thickness of no less than fifty miles.

These rocks afford the most interesting study for the history of our earth. For in them, is preserved, far better than in any historical archives, the memorials of the development of our globe from the remotest times to our own days; and above all, in the numerous fossil remains conserved in their strata, we see the wonderful races of plants and animals that once peopled our world. But the crust of the world is not a finished book yet. Still the rains pour, and the rivers flow, and the waves beat. Still the mountains are washed away, and still the rocks become mud. Still on the floors of the ocean sediment accumulates; and who knows but that one morning there will be a mighty cataclysm, and, behold, a new mountain range! The earth's crust is not so pliable and plastic as it used to be, but still mountains may be in the making in the depths of the sea. Who could have foretold that the ancient Tethys Sea was conceiving the Himalayas in its womb? And who can guess what mountainous surprises the oceans of the world may yet hold? Slowly, imperceptibly, the old continents are worn away, but the rise of a new continent may be as sudden as an earthquake.

AS FAR AS LIVING THINGS CAN ROAM



From the height of Mount Everest, 29,000 feet above the sea-shore, to the depth of the deepest sea, 31,000 feet below the sea-shore, life can exist, and within this range of eleven miles all known life is lived. To these extremities the earth reaches up and down, yet human life is lived, normally, within a fraction of this distance which separates the highest mountain peak from the blackest ocean depth.

'THE NEAREST WE CAN GET TO LIFE'

It is the union of oxygen with the protoplasm inside living cells which produces the energy and warmth and movement, the very life, of all living things; and this union is effected by means of ferments, which are an essential part of all protoplasm, and have remarkable power. It is these ferments which cause yeast to rise, and this picture shows yeast-cells containing ferments magnified 1000 times. Seen under the microscope, these tiny cells appear to be inhabited by countless living things, bubbling over with life; and such a scene is the nearest glimpse that we can get of what happens in the living cell.

THE VERY HOME OF LIFE

A Peep into the Wonder-House which all Life Inhabits—the Holy of Holies of all Living Things

THE SINGLE CELL FROM WHENCE WE SPRANG

ALL living things without exception consist of units called cells, and the living cell is therefore known as the unit of life. Yet this familiar assertion requires the novel qualification that we now have apparent evidence of living beings, such as may cause certain diseases when they invade our bodies, which are so small that we cannot see them, and therefore cannot say what they are like. But all living things, from the smallest that can be discerned by the highest powers of the microscope, up to the largest whale, consist of cells.

Many consist of only one cell, which is the whole individual, and among these *unicellular* creatures are all the bacteria, and many forms of animal life as well. But all the plants and animals which have passed beyond this first stage consist of many cells joined together, and are therefore called *multicellular*. The meaning of "many" in this connection may be gauged from the fact that more than six millions of cells may be found in a drop of human blood equal to two pins' heads.

When we speak of a cell we usually mean a closed space, which may be empty or not —as a prison cell or a cell of bees' wax. Here the wall, or boundary, is the essential thing. The word "cell" was applied to the units of living bodies because the wall was at first supposed to be their essential part. Cells were first discovered rather more than a century ago in plants, the cells of which usually have very marked, strong, and thick cell-walls. The discoverers supposed that these walls were the vital thing, and so they spoke of cells. Sometimes, as they saw, the cells were filled with something; sometimes, as often happens when plant-cells are prepared for seeing under the microscope, the cells appeared to be empty, their contents having dropped out.

But it was only eighty years ago that the real importance of the discovery was realised, and the cell-theory of living things first formulated. Later study showed that what was true of all plants was also true of all animals, though the outlines of the cell and the cell-wall are usually less conspicuous in animals. And later still it was found not only that the bodies of all the higher animals and plants consist of cells, but that they have each of them sprung from a single cell. The reader's body was thus once a single living cell—the most marvellous thing in the known universe.

But we cannot learn anything more about the cell until we correct the old view which thought that the wall *was* the cell, as the walls are the cell of the honeycomb, or the cell of the hermit; and that the contents were just the food or the packing, so to say, of the living being. We understand how the mistake arose, and we need not change the name which expresses the mistake. Nowadays we know that the contents are the essential thing; and when we talk of cells nowadays and study them, and when men devote their lives, or found scientific institutions, for the study of nothing but cells—the science called cytology—they really mean the contents of the cell, not the cell-wall. Indeed, we now know many forms of living tissue in which there are no cell-walls at all, and therefore the word "cell" is really inapplicable. But the contents are there, and they are the vital thing.

They are vital indeed, for they are alive. The cell-contents are the living substance, "the physical basis of life," now known as protoplasm. When we study cells, therefore, we study the protoplasm they contain, and that is the study of life as nearly as man can approach it. Yet the

cell-wall deserves a word or two before we proceed to consider the living substance which the wall encloses.

Though few animal cells, nor even plant cells in their youth, have such cell-walls as first gave us the key to the cell at all, yet cells have membranes, or "skins," of some kind or another. For instance, a red blood-cell is enclosed in a membrane which we cannot see, but which is certainly there, for the cell is elastic and returns to its old shape after it is squeezed.

The Exchange that a Cell of Life Makes with the World outside it

Even the amœba must have some kind of covering surface to its body, though it may be more like the surface of the water in a full tumbler than anything else. At the very least all cells have surfaces; and, as all cells mostly consist of water, these surfaces, whether there be a thick, visible, frontier wall or not, must in some degree behave like other fluid or half-fluid surfaces. When we study the surface of a fluid such as water or mercury, and when we study the behaviour of gases on two sides of such a surface—the air side and the water side—we learn that all sorts of extraordinary and peculiar things are capable of happening.

Now, within the last five years it has been realised that these facts—long familiar as regards membranes and fluid surfaces and so forth, quite apart from living things, and studied as a branch of physics—hold within them the key to many of the facts of the life of cells. The cell is incessantly making exchanges with the world outside it. It breathes, and feeds, and excretes, takes in and gives out gases and solids, and ever requires fresh supplies of water, and disposes of its old supplies. If these processes of exchange should cease, the cell must forthwith die.

Will the Key to the Living World be Found in the Not-Living World?

But the natural laws that govern the behaviour of surfaces, or membranes which are partly penetrable by gases or liquids or by both, apply in the realm of life exactly as they do anywhere else: just as, say, the laws of gravitation or of motion apply to and within a tree or man as to a post or an engine. It is practically certain, therefore, that in a few years many of the problems of life, and of the processes by which life maintains itself, will be solved by the aid of the physicists, who bring their expert knowledge, derived from the non-living world, and begin to show how it contains the key to much of what happens in the world of life. There is a mechanics and a dynamics of the cell; and all the laws of what physicists call *surface-tension*, and *capillarity*, and *osmosis*, and many more of these things, which students of life had hardly even heard of, will teach us to understand *how* the cell manages to breathe, and drink, and feed.

Nay, more: these laws of physics—which men have hitherto studied in the behaviour of mercury in a tube, or of the surface of water when a stick is pushed into it, and so on—these may help us to understand even how the cell moves, and how it absorbs gases into itself, and so smells out its food, and avoids its enemies. All this subject is too undeveloped and difficult for us to discuss at present; but while we put the cell-wall in the background, and correct the first observers who thought the wall was the important thing and the contents negligible, we must remind ourselves of what passes to and fro through that wall, and shall not unduly forget its existence.

Inside the cell is the protoplasm, and here we are in the very holy of holies of life. No fact of protoplasm can be too minute for our attention, and no degree of study can be excessive. Books may easily be devoted to our present knowledge of it, but we do not yet know one-hundred-thousandth part of the whole.

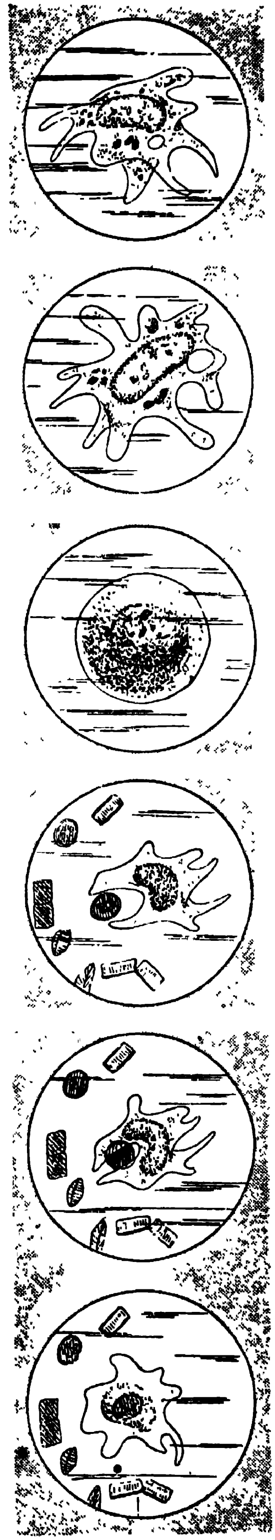
The Knowledge that Future Generations will Gather about Protoplasm

We must use every means of study. The microscope must be pushed to its limits. Chemistry must teach us the composition of protoplasm. All manner of stains and dyes must be applied to cells in order to pick out details and structure otherwise invisible. Cells must be studied in life and in death, and in the process of dying. The movements of their protoplasm, inside them, must be watched, such as the circular movements of the protoplasm just inside the wall of many plant-cells, the crawling movement of the amœba, the kind of dancing movement inside the malaria-parasite, and so forth. Every kind of protoplasm must be studied —which alone is a task for generations to come, since every living species must have a different kind of protoplasm—and then every kind of protoplasm must in turn be studied in every variety and condition—when it is cooled and heated; when it is starved and gorged; when air is denied it, and when the pressure of air is raised; when it is put into oxygen; when alcohol or chloroform is administered to it; when light pours on it; when Röntgen rays are

applied to it; when electricity is passed through it, and so on. The field of study is infinite—literally and strictly infinite. Consider that chemistry makes daily new compounds, each of which acts in certain ways on protoplasm, and in different ways on different kinds of protoplasm, and this one fact alone will show that there can never be any end to our study of living matter and its behaviour. Here, then, we do not hope to learn all about protoplasm, nor yet one billionth part of what there is to learn, but we may make a beginning.

Cells vary widely in their shape, and size, and structure, according to the species they belong to, and the part they have to play in the life of the body. But on the whole there is a type to which they conform, and that type is well represented by such cells as the amœba, or the white cells of our own blood. The amœba consists of a single cell, and is the humblest of known animal creatures; our white cells are tiny parts of the highest form that life has attained. The fact is no less significant that the amœba and the white cell, or leucocyte, should be so similar.

These are not by any means the simplest of known cells, but they are typical complete cells, and all the higher forms of life are derived from cells such as these. We might have chosen such cells as those which constitute microbes, or the red cells of our blood. These would be simpler. For instance, they do not contain a most important and vital part of most cells, called the nucleus. But this simplicity is only apparent. The microbe-cells are degenerate, and represent a fall and defect, as compared with perfect cells, which can live as plants should do—cells of which microbes are the degraded descendants. They are therefore not typical. The red blood-cell is not degenerate in the same sense, but its simplicity is also deceptive. Young red blood-cells have a nucleus, but as they mature they lose it, and give up many possibilities of their lives in order to devote themselves wholly to their mechanical task of porterage in the blood. They also are therefore not typical.



THE SIMPLEST ANIMAL

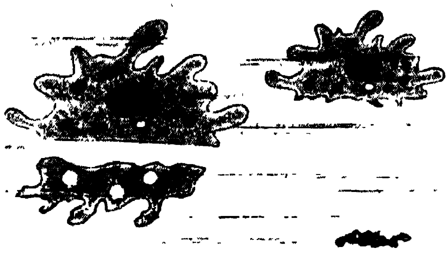
These pictures show how an amœba changes shape almost instantly; and also how the amœba feeds, throwing out parts of itself to pick up specks of food.

The typical cell, such as the amœba or one of our white cells, consists—apart from its covering—of two parts, a nucleus and the rest of the cell outside the nucleus. Though the greater part of the cell usually consists of the protoplasm outside the nucleus, we definitely know that the nucleus is the most important part. We may say that it is all-important, as we shall see. But the rest of the substance of the cell is undoubtedly alive. It is living protoplasm, and shows the characters of protoplasm in their simplest form. The nucleus is also composed of living protoplasm, but here a higher stage has been reached. If, therefore, we desire to study living matter in the simplest form we can discover, we must study the protoplasm of the cell-body.

Naturally, the first question which the microscopist asks, as he looks through the best instrument he can obtain, is what structure this protoplasm displays. Often it looks granular. Sometimes there seems to be a sort of network. At other times, and with other methods of preparation, the protoplasm seems to have a structure resembling foam. Controversy on these appearances has been chronic for many years, but here we need not attempt to decide between them. Protoplasm does certainly seem to have some sort of structure, under the microscope, but probably this structure varies at different times; and it may be that the appearances of a network or of a "foam-structure" are only those of dead protoplasm, not of the living stuff which we seek to understand. We are here travelling far beyond the limits of what the microscope can

reveal, and other methods are necessary. Chemistry gives us aid. First, we find that protoplasm exists in water, and that all living protoplasm consists of water to the extent of about three-quarters of its weight. The remaining quarter is not so easy to describe. It is, of course, so far from being a simple substance, as the name protoplasm might lead us to suppose, that it is really an ever-changing and incalculable mixture, blend, and combination of a vast number of substances, from elements like oxygen, ready for the purpose of combustion, up to complicated substances called proteins, which no chemistry yet can unravel. What we call protoplasm includes all these things. But though they defy description, we can at least definitely assert that certain elements are always found in protoplasm. They are carbon, nitrogen, oxygen, hydrogen, sulphur, and phosphorus. Some others are probably necessary, such as sodium and chlorine, combined to form sodium chloride, or common salt, which appears to play a necessary part in all life. But the six first named are absolutely essential. It is particularly to be observed that these elements, necessary for life, are not rare but common, widely distributed throughout air, land, and sea. And it is no less noteworthy that protoplasm displays to the chemist no element whatever with which he is not perfectly familiar elsewhere. It is crowded with special compounds, met nowhere else, though the elements of which they are compounded are nothing but certain of those elements which make the earth, the sea, the sun, and the stars.

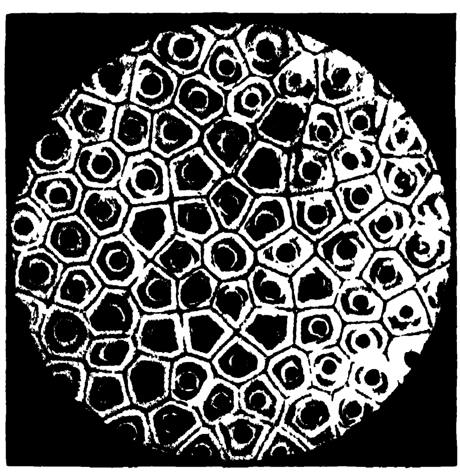
When protoplasm is further analysed, we find that its necessary elements are built up into definite and characteristic groups of compounds, such as salts, starches, sugars, fats or oils, and proteins, which are the most important of all. When we kill protoplasm these are the separate groups of things which we get out of it. If we suppose, however, that they exist, just mixed together, in living protoplasm, as the ingredients of a Christmas pudding are mixed, we lose any chance of understanding how protoplasm lives. If we could analyse living protoplasm—which is impossible, for we must "murder to dissect"—we should doubtless find that these various compounds exist in a sort of further compoundness with each other.



THE THING WITHOUT WHICH A CELL DIES
N[illegible]ll can live without [illegible] which is packed with nucleoplasm. If a cell can be divided so that the [illegible]leus is cut away from one part, that part will die.

They are somehow so much more than merely mixed or packed together that they can exchange atoms and groups of atoms among themselves, in a fashion which no chemist can imitate in any of his experiments. It is this unique capacity for rapid, various, reversible, chemical change and interchange that marks the chemistry of protoplasm. It is the most unstable substance in the world; and if it ceases to be unstable, ever changing and liable to change, it dies. Again we learn the truth that to live is to change.

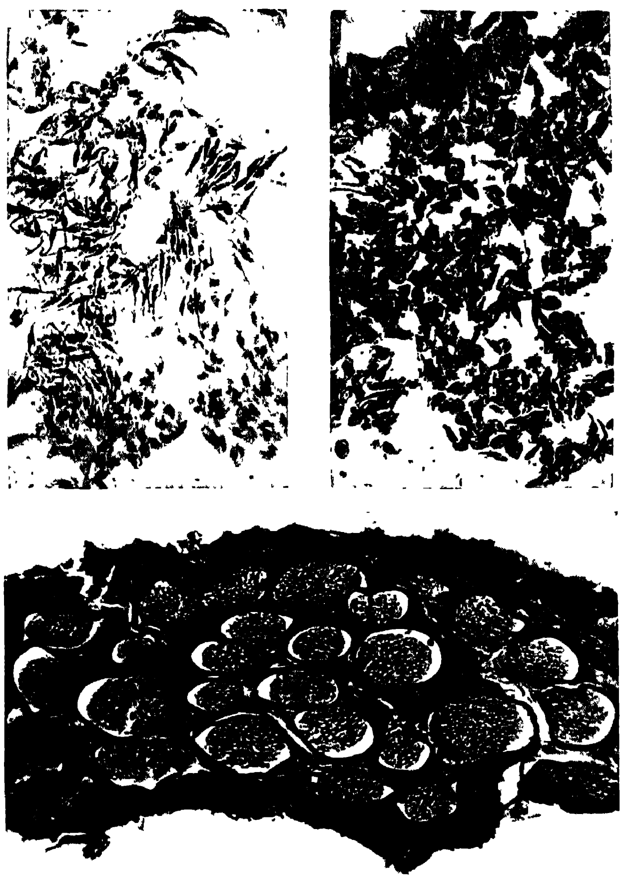
One more fact about the chemistry of protoplasm is essential. It is always burning away, and therefore it always requires oxygen. In one word, it breathes; and every living cell breathes continuously or dies. Recent extraordinary experiments by French scientists suggest that this breathing may sometimes be made very slow indeed, if not even suspended, so that the living cell may almost cease to live for a time, but will resume its life and breathing when water is supplied to it. Here is the explanation of the germination of dried seeds which may be a century old. But these cases where life seems temporarily suspended or relaxed are just the exceptions which prove the rule. The seeds cannot go on breathing, because the indispensable water, the medium of all the chemical changes of life, is absent. Supply the water, and life starts again.



IMITATIONS OF LIFE-CELLS
Parts of an artificial product made in a laboratory showing how closely cells of life can be imitated in artificial structure

Nothing in modern research takes us farther into the hidden places of life than these experiments.

If protoplasm must take in oxygen and use it up in order to live, we must satisfy ourselves as to how this happens. The oxygen enters the cell, and reaches the protoplasm within, by passing through the exterior of the cell: and we have seen that the physicists are helping the students of life to understand the forces which move the oxygen inwards. And now, we may suppose, it feeds the living flame, as we may metaphorically call it, just as oxygen feeds the flame of a candle or a fire. That is not what happens, and could not be what happens. No living thing can exist at the temperature of a candle-flame: and oxygen will not combine with the materials of protoplasm at any such low temperatures as those of living things. Let the student of fuel, the motorist, the housemaid, the engineer, the cook, imagine a fuel which is three-fourths water, a fuel much more than dripping wet, and then imagine the task of getting that fuel to burn at the temperature of one's skin.



TYPES OF THE CELLS THAT HUMAN LIFE INHABITS

Living things may be animal or vegetable, large or small; they may flourish in the lowest and blackest depths of the ocean, or upon the dizziest crag, but they all consist of cells, of which these are three types, taken from the human body. The lower picture shows fibres connecting nerve-cells

Nowhere but inside living protoplasm can such an astonishing thing be done, and it can only be done because the burning or combustion, or union with oxygen, of protoplasm is a unique process, vastly different from anything that naturally occurs, or can even be produced by experiment, elsewhere. The protoplasm of the living cell takes the oxygen into its very substance, and its combination, which produces the energy, the warmth, the movement, of all living things, is effected by means of certain special agents called ferments, which are made by protoplasm, or, rather, which are essential parts of all living protoplasm.

So wonderful are these ferments, by which protoplasm is burnt or oxidised, that not only are they capable of conducting this operation under conditions which are utterly impossible elsewhere, but they can control its rate and its character for the particular convenience of the protoplasm in question. The living cells that compose any muscle, for instance, quietly live and breathe by using a little oxygen, so long as they are not called upon to contract. But the ferments they contain are able to hasten the rate of combustion instantly a thousand-fold when a nerve gives the order, and the muscle-cells are set to work.

Again, there are ferments in some kinds of protoplasm—those found in the microbes, discovered by Pasteur, which cannot live in the presence of air—which are more wonderful still. These microbes live, away from the air, in substances such as beef-jelly, which consist of compounds of oxygen. These compounds have to be broken up and decomposed, and the oxygen sucked out of them, if the microbes are to live, and this is done by special ferments which are contained in the protoplasm of the microbes. It is as if a drowning man could decompose the water—a compound of oxygen and hydrogen—which is suffocating him, and could breathe the oxygen thus obtained.

The general protoplasm of the cell often contains all manner of things which are not part of it. They may be the remains of a feast, as when the amœba is digesting a

meal, or when a leucocyte is digesting a microbe or a malaria-parasite. In other cases, the protoplasm may contain special products of its own creative power, such as the green specks of chlorophyll which we find in the cells of green leaves, and which are there for the purpose of the plant's life. Also, the cell-protoplasm may contain any number of kinds of foreign substances which have been administered to it, some harmless, but most of them poisonous. These are in the protoplasm, but not of it; and the same is true of many waste products of the life of the protoplasm, which it is in process of discharging.

The Wonderful Nucleus which is the Centre of the Life of the Cell

Let us turn now to the nucleus of our cell. A simple round bacterium, such as causes inflammation, has no nucleus. Considering that it is perhaps only one twenty-five-thousandth of an inch in diameter, the fact is not surprising. But this is a degenerate cell. It may very likely resemble, in its degenerate state, earlier cells of long ago, which existed before the amœba or the humblest known plants, and which had not yet developed a nucleus. We must be careful not to forget that the nucleus is really a high development and elaboration of the cell, and that it may have taken as many ages for its evolution as, say, the vertebrate skull has taken, or the eye, or the speech-centre in the brain of man.

The first fact we learn about the nucleus is that it is the centre of the life of the cell, just as the skull and its contents are the centre of our lives, and any part of the body which is cut away from the head must die. Yet, as we know, the head is a recent invention, so to say. Similarly, the nucleus, though it is the newest part of the cell, has made itself essential to the cell's existence.

The Nerve which Tells Us when our Shoe Pinches

If any cell be cut in such a way that the nucleus remains in one portion and the other contains none of the nucleus, that other part will die. But the part which contains the nucleus will not die. On the contrary, it will make good its loss, and be none the worse. This extraordinary fact is true of all cells whatever. What we call nerves are prolongations of the protoplasm of nerve-cells. The nerve which informs us when our shoe pinches is a prolongation of a cell—or, rather, of many cells—in the spinal cord, perhaps three feet or more away from our corns. The life of the nerve depends upon the nucleus in the nerve-cell, just as we see in the amœba. If the nerve be divided, the part next the cell, which contains the nucleus, is none the worse, just as the protoplasm which is still connected with the nucleus of the divided amœba is none the worse. But the part of the nerve which has been separated from the nucleus in the nerve-cell immediately degenerates and dies, just like the amputated piece of the amœba. The law that the nucleus is the centre of the nutrition and life of the cell is therefore proved equally true of the lowest and highest types of nucleated cell—the amœba at one end of the scale, and a human nerve-cell at the other. As we shall later see, cells divide, and when they do so the nucleus divides also—indeed, the nucleus always divides first—and thus each half of the cell has a portion of nucleus in it, and can live and complete itself.

We may go further, especially in the light of what we learn from the study of the germ-cells from which new individuals spring, and we may say not merely that the nucleus is the vital centre of the cell, but that it *is* the real cell—the real living being.

The Cell which Gives Rise to New Individuals

The rest of the cell has a subordinate and dependent life, which ceases when it parts from the nucleus; and we cannot doubt that the rest of the cell simply exists for the nucleus. It protects the nucleus by its mere presence. It takes in air and food material, and prepares them, no doubt, for the service of the nucleus. But it is possible in some cases to shake a cell in such a fashion that the nucleus drops out. This naked nucleus can not only live, but can give rise—if it be the nucleus of a germ-cell—to new individuals, in whom nothing is lacking. But a cell which has lost its nucleus will soon die and come to nothing.

Soon we shall devote ourselves to studying the supreme business of the nucleus, which is to divide and form new cells, and meanwhile we have noted the function of the nucleus in nutrition. But before we study its function for the reproduction of the cell, and for all that depends upon it, we must realise how cells are built up into individuals, and what becomes of them.

The lowest plants and animals consist simply of one cell apiece. In time the cell divides and forms two individuals, each consisting of one cell, as before, as we see in the picture on page 152. All the higher plants and animals begin their individual existence as one cell also, and that cell divides, just as the amœba divides, but in

this case the two daughter-cells stick together. They divide again and again, until we have a multitude of cells. Of these, some turn into skin, others into bone, others into muscle and nerve; and, lo! here is a living animal or plant.

All this depends on cell-division, and, indeed, division is as much an essential and vital part of the cell's business as is its own individual maintenance. It lives to divide. This division is one of the most wonderful and mysterious facts in all science, and is still the secret of the nucleus.

ONE OF THE WONDERS OF LIFE
All cells must divide, as this is doing. The cell's surface is its "mouth," so that the division of the cell, and *the creation of more surface area*, are the only way in which the cell can obtain food enough as it grows. From this division of cells proceed all the variety and progress of life

But why should a cell divide at all? Why should not an amœba grow and grow indefinitely, without dividing? The whole face of life would be different if this were so; and we seek a reason for this elaborate, difficult, and dangerous business which the amœba, and cells of life of every kind and shape, undertake when one would think that if they *must* grow, they might as well just grow bigger.

The answer is that cells cannot afford to grow too big. The biggest cell-bodies we know—not counting such protrusions as nerves—are very tiny. Herbert Spencer was the first to show the reason. The bigger a cell grows, the more stuff is there in it, in proportion to its surface. A small marble, similarly, has much more surface in proportion to its weight than a big marble. Therefore the time comes when the cell has too much living matter in it for its surface to feed. Its surface is, let us say, its mouth, and, as it grows, its mouth does not keep pace with it. Let now this overgrown cell divide into two, and it at once gets much more surface—the surface of two new cells put together—through which to feed and ventilate the life of the same quantity of living matter. That is why all cells must divide, and why no cells ever grow beyond a very tiny size. The consequences of this simple fact are gigantic, for from cell-division proceed all the variety and all the progress of the living world.

Lastly, we must note that no cell lives indefinitely. If it be an amœba or a microbe, and even if it escape poisoning or starvation or other accident, such as all forms of life may encounter and succumb to, the time comes when it must divide or stop growing. To stop growing, *in one way or in another*, is to die. The cell obeys the law of life, which is to make more life; and rather than die of arrested growth and over-nutrition it divides. In so doing, it in a sense ceases to exist. Nothing has died exactly, for there is no corpse. But the amœba that was is not any longer. In its place there are two others which have grown from its halves.

As for the cells of those plants and animals which consist of more than one cell, they die also. It is literally true that many cells of our bodies die every day, and the body as a whole will die too. Before doing so it may have renewed its life in its own wonderful way, just as the amœba, before losing its own individual existence, renewed its life. But the fact of death remains; and our science of life will be very crude and useless unless we can somehow explain this fact of death. How can death, as an ordained and natural fact, be reconciled with this universal striving towards life?

THE EARLIEST FORMS OF LIFE OF WHICH RECORDS EXIST TO-DAY
This picture shows us the kind of animals that lived millions of years before the great coal-forests covered England. At that time the waters covered the greater part of the earth, and were inhabited by trilobites and the ancestors of corals, cuttle-fishes, and sponges.

THE SMILING PLAIN ENRICHED BY FORCES THAT BRING LIFE DOWN FROM THE HILLS

The fertile plain surrounded by hills, one of the pleasing features of our British landscape, is the result of a combination of forces, chiefly the action of water, bringing down the waste of the hills, and a greater variety of the constituents of good soils than the plain would otherwise obtain.

WHAT THE SOIL IS MADE OF

The Qualities and Forces for ever Working Under our Feet to Sustain the Life of a Garden

THE THINGS THAT MAKE THE EARTH FERTILE

WE have now arrived at the point when we have realised that the earth on which we walk and play and build, and into which we penetrate in order to extract vast hordes of mineral wealth, is not to be regarded as a "lifeless clod," but rather as a mass of matter teeming with myriad forms of living things. We have, moreover, realised that the struggle for existence which results in the survival of the fittest, so far from being limited to what goes on above the surface of the earth, is in reality just as keen and remorseless underground; in fact, it would be most true to say that the real struggle for existence in animate nature begins in the soil, which we have already come to regard as a battlefield where opposing forces are for ever at war.

Having considered the origin and history of this soil, and the manner of its formation, and in particular having realised that it is being constantly made and reproduced day by day, year by year, and from age to age, the next question arising is: What is the soil made of? To this question we must now turn our attention. It is obviously impossible to deal in great detail with all the processes and constituents which render the soil a source of nutriment for plant life, but it is necessary that we should study these aspects of our subject as far as possible. We must endeavour to realise at once that the soil is in very truth the beginning of all things in this world. From it, directly or indirectly, come all forms of life; and on its internal, chemical, and biological processes depend the existence and the production of almost everything that we know.

Let us be clear as to our terms. Originally the soil is simply the product of rocks of various kinds, which, by the varied processes of "weathering," have been reduced to a more or less fine state of sub-division; and its exact nature, therefore, to a great extent depends upon the nature of the geographical formation from which it is derived. This decay of the rock crust of the earth at the hands of the weather produces what is sometimes called waste, and this waste is the forerunner of the soil. The process of weathering and the production of the waste is continuous, and goes on for ever; and it may therefore be asked how it is that all parts of the earth are not covered with this production, why it is accumulated in some places more than in others, and why it is in some places entirely absent.

It is, of course, a commonplace of observation that there are vast areas of bare rocks and barren mountains on which there is no soil at all. The explanation of this occurrence is to be found in the fact that the waste is removed after it is loosened, principally by the action of water. The waste has been removed to form soil which has gone elsewhere. Where it is formed upon a slope, it will be readily understood that the smaller particles on the surface are moved lower down with every drop of water trickling along the surface. The more potent the force of water thus acting, the faster and more complete will be the removal of the soil particles; and in addition to this the whole mass of loosened waste moves slowly downwards in obedience to the law of gravity, descending with greater speed on the surface, and more slowly underneath.

Besides this direct action of water in thus washing away the soil, such conditions as changes of temperature, dryness and dampness, frost and snow, all aid the movement downward; and still other forces with a similar tendency are the growth and decay of the roots of plants and the action of earthworms, ants, and other burrowing animals, bringing to the surface small particles which are readily removed. All these forces

act more powerfully on the top; and it is for this reason that the superficial part of the waste moves faster than that underneath. Finally, it need hardly be said that the steeper the slopes upon which these changes take place, the faster is the removal of the waste to the low land beneath.

It is, of course, as the result of the combination of all these forces that we find the fertile valley and plain lying at the foot of mountain ranges; and this also explains why the soil finest in texture is to be found near the surface, a fact of the very greatest advantage to many plants, though unfavourable to certain kinds of trees.

Why we May Find Good Farms and Bad Farms Side by Side

We may say that soils can be divided into two classes—namely, local, and those which have been transported, the local kind consisting of the waste still remaining upon the surface of the rocks from which it has been produced, the other being soil which, by one or many of these forces, has been carried from its source of origin. Hence it is that local soils vary so much in their character and fertility.

It is in consequence of this, also, that we may thus constantly see a remarkable difference in the value of the land on two adjacent farms, one of which may be situated on rocks which give a valuable soil, and the other on rocks giving a poor one; or one being on the right and the other on the wrong side of the valley. The valuable soils of our meadows and valleys obtain their fertility from the fact that they contain a much greater variety of constituents than is found in local soils, these local soils being more restricted in the variety of plants for which they are suitable.

The Precious Things that Water Washes Down the Sides of the Hills

The form taken by waste swept down by streams depends very largely upon the kind of stream concerned. If a mountain torrent receives a great quantity of coarse waste from a valley with steep sides, a great deal of it is carried into the valley itself; and it does not reach the main river into which the stream ultimately flows. The ultimate result of such a deposit is the formation of a mass of soil in a form somewhat resembling a cone, which spreads from the mouth of the ravine into the wider main valley below. Such a formation is known as an alluvial fan. Many other forms of the ultimate disposition of this soil also occur, chiefly due to the behaviour of the stream which carries the waste.

The constitution of the soil presents, therefore, infinite variation. There is a continuous chain of stages of transition from the rock to what we may term the finished product. Very well marked links in this chain are what we know as loam, sand, and gravel. It must be remembered that the rocks thus decomposed vary immensely in the mineral salts which they contain, and, in addition, there is great variation in the amount of decaying animal and vegetable matter which finds its way into the soil. Most important, too, is the variation in the capacity of different soils to absorb, to hold, and to give up the water in them.

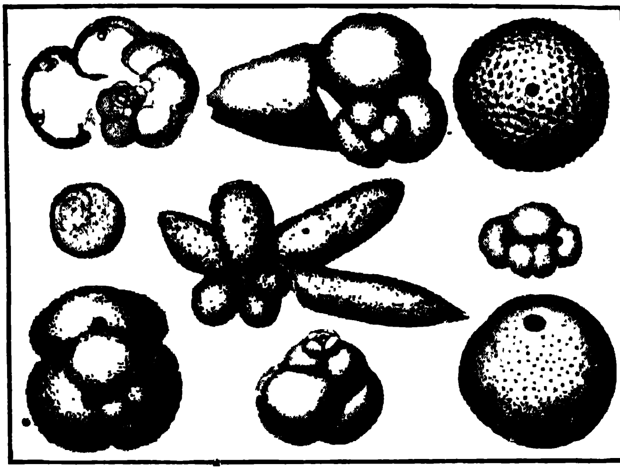
As notable examples of these variations we need only instance the sand on the bank of a mountain stream, which is largely composed of quartz, with that on the seashore, which is calcareous in origin and impregnated with salt; or we may compare the granite bed of a desert, with its utter absence of soil, with loam, where there has been for many centuries an intermixture with decaying vegetation. But, no matter what these differences may be, the soil becomes a source of nourishment for plant life only when its interstices are filled with water during the time when the plant is manufacturing its organic constituents.

The Water that Permeates the Earth, Breaks up Rocks, and Fertilises the Soil

To meet this demand we have a multitude of streams entering lakes, and rivers reaching the sea, thus supplying the atmosphere with water in the form of vapour, ultimately becoming snow, or rain, or dew. On to the dry and barren land it falls, and into the porous earth it permeates, filling up every nook and cranny. Its ultimate descent is here and there impeded by coming into contact with an impervious layer of rock, on the surface of which the water spreads out from side to side, or is driven up again, emerging as a spring. Moreover, the earth itself, which contains large quantities of decaying vegetable matter, is capable of absorbing vapour from the atmosphere, and also of producing carbonic and nitric acids, because these important constituents are derived from the decay of dead plants themselves. Thus, the water in the soil is rendered acid, and is enabled to cause decomposition in the rocks which it encounters as it traverses the ground.

From this process is produced many of the most important substances found in the soil. Thus, felspar is decomposed by acid water, the alkalies of the felspars

combining with carbonic acid and nitric acid and forming soluble salts, other substances remaining behind as clay. Iron also is in this way converted into soluble salts. Other materials which offer great resistance to this decomposition, such as mica and quartz, remain unchanged in the form of glittering scales which we find mixed with the clay. But even these, in time, are decomposed by the water containing acids.

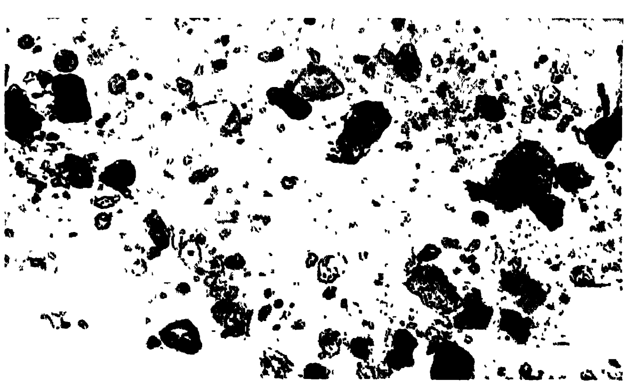


ONCE-LIVING THINGS WHICH HELP TO MAKE A GARDEN
These are the creatures, once alive in the sea, which make up chalk, one of the most precious foundations a garden can have, providing the elements needed by the bacteria upon which the earth's fertility depends.

The total result of all these chemical operations is a soil which, though varying somewhat, according to the nature of the rock from which it was derived, contains a certain amount of clay, sand, or mica, and differs in colour, according to the iron compounds contained within it. If a detailed chemical analysis of such soils be made, with a view to ascertaining what substances they contain that are of special value to plants, we find the following: potash, soda, lime, magnesia, alumina, ferrous and ferric oxides, manganese, chlorine, sulphuric acid, phosphoric acid, silica, and carbonic acid. These occur in greater or less proportion, along with minute traces of many other substances.

THE WONDER OF A COMMON THING
This is a microscopic photograph of the familiar Tripoli powder used for polishing. It is made up of tiny plants which have the power of extracting flint from sea-water and weaving it into its own fabric. As it accumulates in the bed of the sea, it ultimately comes into the soil, and is a valuable factor in promoting fertility.

The greater mass of the rocks which enter into the formation of the solid crust of our earth belong to the group of flints (or silicates) and quartz. Next to these, limestone and dolomite are the most abundant, and these consist mainly of lime and carbonate of magnesium, always, however, containing a mixture of alumina, silicic acid, ferrous oxide, manganese, and traces of alkalies, combined with acids. Much of the carbonate of magnesium, and some of the other elements, is slowly dissolved by the acidulated water, and the remains of this process consist of a loamy mass, which differs in colour according to the iron it contains, but is very like the clay formed from felspar. The important point in this connection is that, on a chemical analysis of this loam being made, we find that the same constituents are present as are found, say, in soil produced from the silicates. In other words, the *qualitative* analysis of soil derived from different sources proves that the elements necessary for the nutrition of plants are present in all cases. The difference in these soils consists in the relative proportions of the elements present; it is in *quantity*, and not in quality.



THE GRAINS OF SAND WHICH GOOD SOIL NEEDS
From the roughness and shape of these grains of sand, much magnified, it is easy to understand how sand breaks up soil and encourages percolation, with a somewhat free admission of both air and warmth.

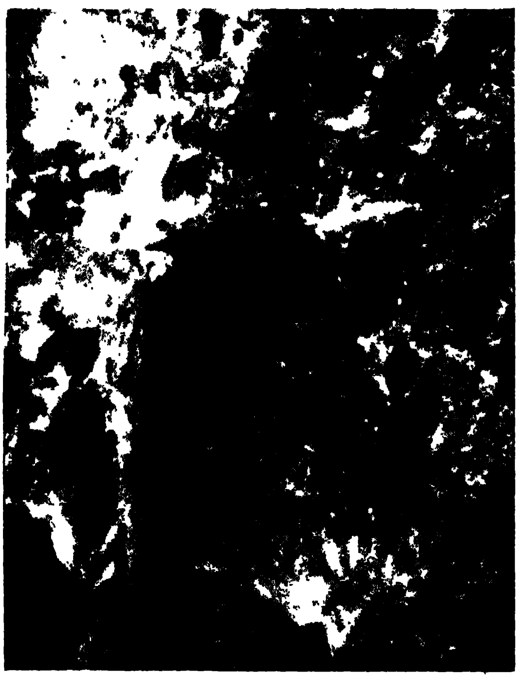
So far we have considered mainly the action of the water containing acids as a great agent in producing soils, but in addition to this factor it is important to remember that changes of temperature play a part, especially in connection with the freezing of

water in the interstices of the rocks. The mere mechanical action of water also assists; and the dead roots of plants, becoming mixed with the decomposition of the rocks, thus add their component parts. The sum total of the product of all these varied and complicated changes is what we call soil or mould, or simply earth. The special part of that soil which is formed by the decay of dead plants, which gives rise to a brown or black mass, is known as "humus," a very important constituent of soil from the point of view of vegetation. Soil which contains a large quantity of humus is frequently spoken of as vegetable mould.

All kinds of soil, but especially those which contain much clay or humus, hold within them gases as well as water and salts. The water in this soil is retained there in virtue of its property of adhesion to the particles of earth. So, too, the salts are retained in similar manner. If we examine water at the deepest level of the soil it is found that it contains much less salts in solution than water near the surface, showing that the salts are absorbed as the water penetrates down.

From the point of view of plant life, the nature and composition of the surface soil is of paramount importance. In order that this surface soil should be easily cultivated, it is necessary that air and water should be able to penetrate into it with ease. For this reason, clay, which is impervious to both of these, is particularly unsuited for agricultural purposes. It is also important, however, that the air and water, having gained an entrance, should be held in the soil for such a period as will enable them to do their work. So it is that sandy soil is also unsuitable, although for an exactly opposite reason—it is too porous. Lava in its fresh state is absolutely unfertile, but after it has become exposed for a time to the process of weathering, plant life begins to make its appearance in it, and as time goes on this plant life grows. When the lava becomes thoroughly disintegrated, it produces an extremely fertile medium. This is extremely well seen on the slopes of Mount Vesuvius, which are barren of vegetation almost to the very base, while the district of Campania surrounding them is extremely fertile.

The soil which is formed as a result of a clearance of forests, where there has been a vast production of vegetable mould, is very rich. Such soil is often spoken of as virgin soil; and it is this which gives the pioneer in Canada and New Zealand, and other parts of the Empire, the amazing crops with which we are all familiar.



HOW LAVA BREAKS UP SO THAT LIFE MAY GROW IN IT

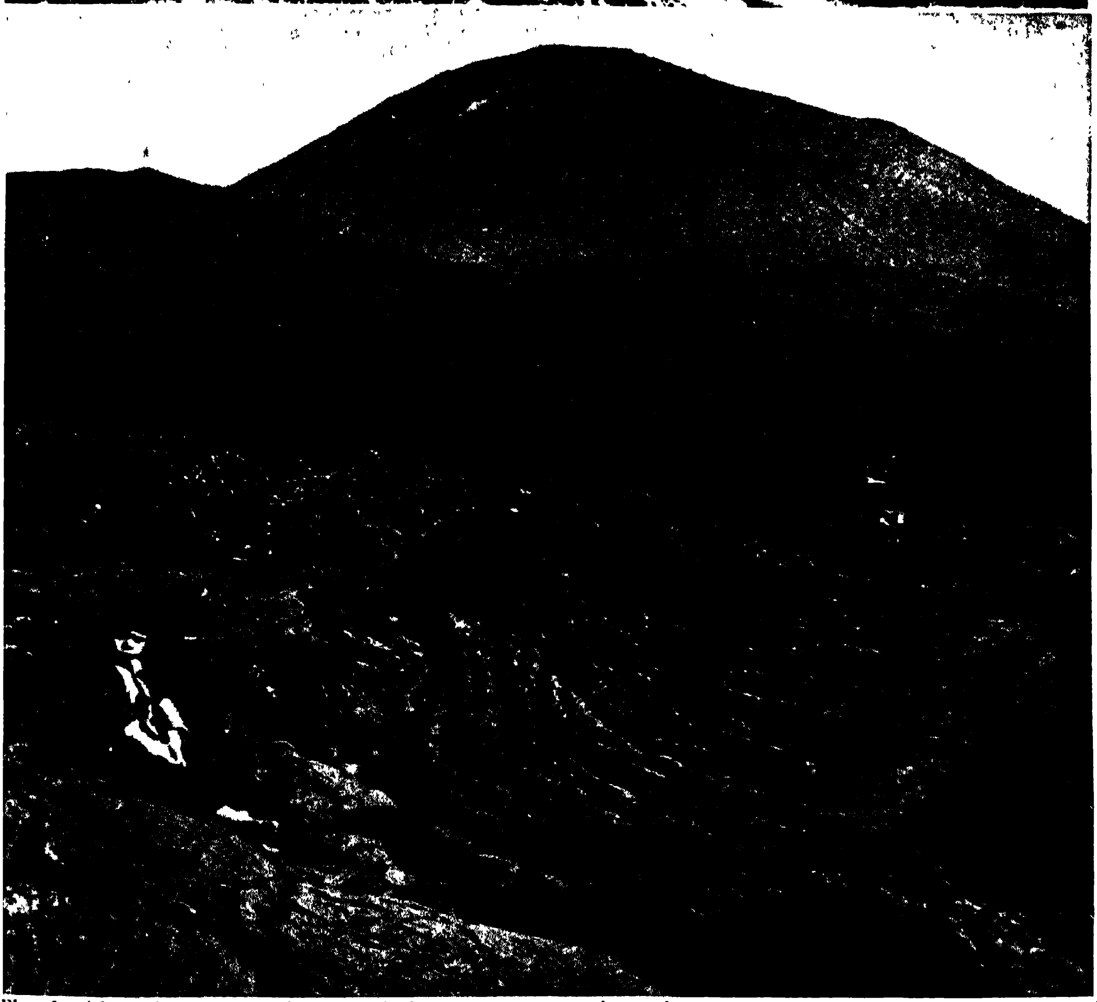
This is a photograph of a piece of lava under the microscope, clearly showing how life may find a home in it after disintegration.

Soils of an alluvial nature become fertile once they have passed through the stage of swamp or bog. Some very fertile soils have been deposited as such by the action of the wind, an example of which is seen in Northern China, where soil has been carried by the wind from the deserts of Central Asia. Other soils, though not fertile themselves, will contain extremely important elements, an example of which is to be seen in the nitrate deposits of Chili. This nitrate deposit is widely used as a fertiliser, being added to soils which are deficient in nitrogen.

The depth of a fertile soil varies extremely. On a chalky down, for example, it may be as little as three or four inches; in other situations it may be as much as fourteen or fifteen inches.

The most perfect soil, from the point of view of the agriculturist, is one which is broken up into fine particles, and consists of nearly equal parts of clay, sand, chalk, and vegetable mould rich in humus. A good soil contains from 50 to 60 per cent. of sand, and from 25 to 30 per cent. of clay, with from 7 to 10 per cent. of limestone or chalk. Sand, clay, and humus make up about 90 per cent. of an ordinary fertile soil. The colour variation in soil is largely due to the presence of iron compounds.

LIFE FROM THE CINDERS OF VESUVIUS



The fertility of the earth is one of the constant wonders of Nature; nothing seems to be beyond the reach of Life. The lower picture on this page shows a stream of lava from Vesuvius. The picture at the top shows how, after years of disintegration by sun and wind and water, these cinders, thrown up red-hot from the molten furnace inside the earth, become fertile as a garden.

Other minerals also play a part in this, but it is the oxide of iron which imparts to the soil its reddish tint.

The consistency of the soil—its mechanical texture—varies because of the difference in the rocks from which it comes. A heavy soil is one composed chiefly of clay; and when this clay is very near the surface the soil is called "cold." Any soil with 50 per cent. or more of clay is regarded as a clay soil. Loam contains from 25 to 30 per cent. of clay, and is a favourite variety. A loamy clay, or a clay loam, is made up of proportions between these two, and has a clay subsoil. A sandy soil, to be suitable for cultivation, must contain less than 10 per cent. of clay, and a sandy loam less than 25 per cent. Soils which are superimposed on limestone or chalk are regarded as calcareous soils should they contain over 20 per cent. of either limestone or chalk.

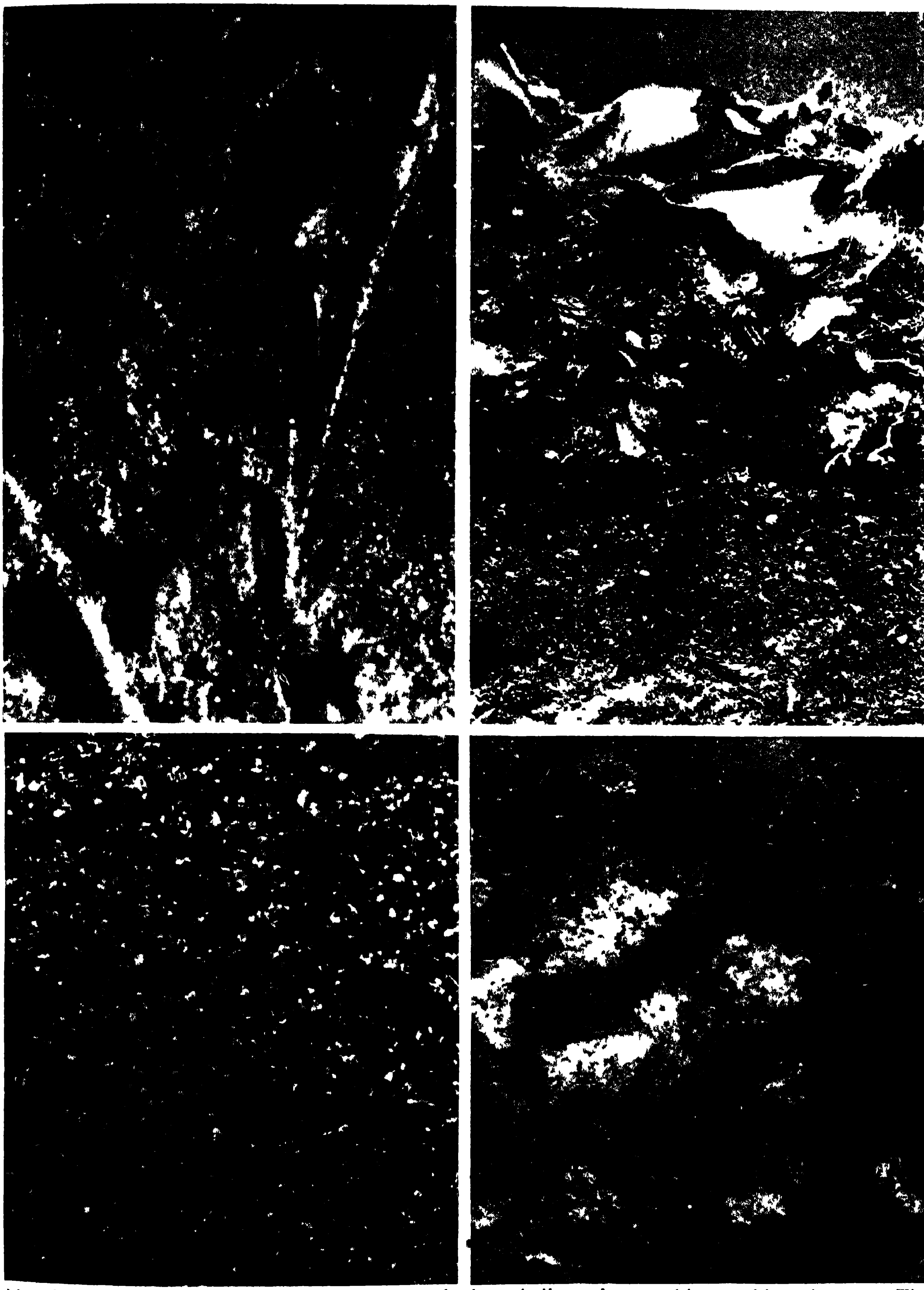

THE UPPER LAYERS OF THE EARTH
A photograph in a gravel-pit showing the thin film of fertile earth, resting on gravel—of which the upper part is weathered—and ultimately on clay.

For the varied purposes of soil, the four substances of clay, sand, chalk, and humus are essential. The power to retain moisture is provided by the clay, which also gives a certain tenacity to the soil. The sandy element encourages percolation, easy breaking up, and a somewhat free admission of both air and warmth. The chalk, or limestone, adds important nutritive qualities, and acts as a neutraliser of acidity and an aid in decomposition and nitrification. The humus is very valuable for many reasons. It assists soil to keep moist, and from its own decomposition promotes warmth and carbonic acid, which, when dissolved, enables salts to be carried to the roots of plants. Moreover, the decomposition of humus provides ammonia, which is intimately connected with the supply of nitrogen to the plant.

It thus appears that of the actual chemical elements known to science there are at least fifteen which have very close relationships with plant life. Among these, especially important are carbon, oxygen, nitrogen, hydrogen, sulphur, phosphorus, potassium, calcium, magnesium, sodium, and iron. All of these are absolutely essential; and should any of them become absent in any soil, they must be renewed, by artificial means or otherwise. This is especially true of nitrogen, potassium, phosphorus, and calcium, but of all these elements the most important is carbon, inasmuch as it is the principal constituent of the plants themselves. It can now be readily understood that different soils have extremely different values and importance for purposes of plant life. Most people know that natural vegetation in any locality is found to vary according to the nature of the soil. Thus, sand is useless for growing crops, on account of its being extremely porous, which renders it unable to retain water, and it is, moreover, very lacking in organic matter for plant food, while under the action of a powerful sun it also becomes too hot. Sand is exactly the opposite of clay, which is tenacious, holding both water and air, and therefore becoming cold in wet weather and baking hard in hot times. These two soils are examples of extreme variations, the clay requiring sand and humus to loosen its texture, the sand requiring humus and clay to make it workable.

Modern science, therefore, has shown that it is of primary importance for the cultivator to be able to ascertain what constituents are present in any kind of soil he proposes to utilise, and particularly in what proportion they are there. With this knowledge he can counteract any excess of one constituent, whether sand, clay, chalk, or peat, by adding to it the material lacking, and by doing this in such a way and in such quantity as to produce a fertile loam.

THE COMMON FACTORS IN THE SOIL



The chief things essential to a good soil are sand, clay, chalk, and vegetable mould, or humus The sand, as seen from the magnified sand grains in this page, is porous and encourages the permeation of water and air ; the clay retains moisture and gives tenacity to the soil ; the chalk has valuable qualities in nitrifying the soil and in other ways ; and the decay of the mould promotes and provides ammonia and other valuable elements for the development of plant life.

A SWARM OF FLYING FOXES FAST ASLEEP

A swarm of flying foxes—the fruit-bats with the long, fox-like faces—may often be seen hanging asleep on a tree like this in India They pillage the fruit-trees, and at the close of day a long procession of these bats may be seen on its way to pillage the fruit-trees.

EVOLUTION BEFORE OUR EYES

The Way in Which the Life of the Animal Kingdom now Helps to Solve the Mystery of the Past

LIVING CREATURES ON THE BORDER-LINE

THE naturalist is a highly scientific detective. The mystery which he essays to unravel is the story of animate creation, a profound and fascinating scheme. He must be able not only to detect the difference between a deer and an antelope, but to recognise at once the characteristics which separate both from other families; and must be able, further, to trace the features by which all animals are related in the scheme of life. The casual observer would set down newt and salamander as reptiles, and the whale as a fish, though the tyro in zoology knows that the first two are amphibia and the third a mammal.

Not from motives of pedantry are the distinctions made; the distinctions are priceless guides to the scheme of things that the naturalist has to study. He must know things as they are individually, how they are related one to another, how they came to the form and characteristics by which we know them. External evidences are not enough for him. The zoologist must have the aid of the comparative anatomist to tell him how animals, greatly differing in appearance, agree well enough in vital structural detail to be classed in the same order. To trace the story of the development of a species our detective must have the assistance of the embryologist, for the magic of past history is revealed in the prenatal stages as by no other method known to science.

Lastly, there is the testimony of the rocks, brought to light by the palæontologist, the student of the fossil remains of what, millions of years ago, were animals. These tell us what the ancestors of existing types were like. There we see how new species, diverging from the original stock, grew up; and the embryo of existing representatives makes plain to us much of the detail of the story. The naturalist works on from clue to clue until finally he is able to present the whole enthralling romance of the pageant of life. Casting round, in the light of knowledge gleaned by way of these channels, he is able to trace the age-old progress of evolution to its newest chapter, now unfolding before our eyes. He can trace life down many a blind alley, flash a light upon creatures which have missed their way, so to speak, or have specialised too much and become freaks.

Some of these creatures remain, as milestones, marking the way along which the great currents of life have surged. Little columns of limestone mark the measured mile in the Clyde over which battleships and ocean liners run their trials. These mileposts are the fossilised remains of billions of living creatures of the sea. Changed to stone, they serve to point the course of mechanical monsters of newer deeps. And some such purpose in Nature is served by groups of curious creatures at which we may now glance. Scientific classification is, of course, disregarded here; the animals chosen are those which may be considered, in some sort, steps—though not, of course, successive steps—in the scheme of living things.

We may begin with the tunicate and the lamprey. Here are two of Nature's children which have obstinately refused, or neglected, to grow up. The lamprey is not a fish, though it lives in sea and river; it has neither fins, nor scales, nor jaws, though its sucker-mouth and tongue have teeth. It set out to be a vertebrate—a backboned animal—and the primal impulse still animates the embryo and the free-swimming young. But the promised backbone never arrives, and the lamprey, like the hideous hagfish, remains lower than the true fishes, if higher than the worms.

The tunicate is a still more glaring instance of good intentions unrealised. The adult

is invested in a sort of tunic, from which it takes its name. The young tunicate starts life fairly well, with a notochord and a supporting rod in the tail. Now, the notochord is simply a fibro-cellular cord or rod found in the embryo of all backboned creatures from man to mouse, and it is replaced in the perfect form by the spinal column. Equipped with this physical good intention, the young tunicate begins its career a free-swimming, active little animal, alert and industrious as a tadpole, with every prospect of attaining to the dignity of a backbone.

The Little Micawber for Whom Nothing Ever Turns Up

The tunicate proves, however, to be a Micawber for whom "something" never turns up. It eats and swims and busies itself with futile assiduity. Inherited inertia supervenes; the nervous system degenerates; the tail is absorbed, the eye disappears, the notochord breaks its promise, or proves barren; and the creature, in its adult form, anchors itself at a convenient place, and throws about itself a cloak whose texture resembles the cellulose of which the walls of plant cells are composed. The promise of the higher life is forgotten, and a hopeless animal of the lowest type, comprising both sexes within the one frame, remains as a finger-post to the past days when Nature was evolving her types.

We find greater wonders in another order low on the ladder of life—in the jelly-fishes. Here, in the medusæ, for example, we have a creature compounded almost entirely of sea-water, but so combined as almost to pass man's comprehension. This mass of water, confined in a sort of web, makes up an animal with appetite and passions, with power to inflict injury, to capture and consume its prey. It is equipped with that gift of light which enables it to turn the seas on summer nights apparently to liquid silver.

The Creature Chiefly Made of Water, with Children Unlike Itself

This jelly-fish gives birth to young entirely unlike itself. The young retain their first form throughout life, but give birth to offspring with the form of their grandparents. From the jelly-fish proceeds young in no way resembling itself, and from these issue jelly-fish. And this creature, about whose life-story these wonders congregate, is chiefly sea-water. From a specimen weighing four or five pounds there remains, after evaporation, only a film of solid weighing four or five grains.

A Scottish audience, before whom a learned professor was lecturing on this subject, contained a thoughtful farmer whose land lay upon the coast. "Is it true," he privately asked the lecturer at the close—"is it really true that these jelly-fish are chiefly water?" He was assured that such is the case. "Well," he said, "I have been employing men and horses to cart tons of them from the coast as manure for my land." He was not consoled when assured that in a ton-weight of newly gathered medusæ there would remain but four pounds of solid matter after the water had evaporated.

Some steps higher in the scale we meet a function more surprising than the stinging power of the jelly-fish—the genuine electric discharge of the electric fishes, the electric eel, the cat-fish, and the electric ray, or torpedo. The early creatures of the sea probably knew all about the hurtful qualities of the stinging jelly-fish; and it was probably very early in the story of civilisation that man discovered that, though a healthy discharge from an electric eel sufficed to stun him, the same discharge, carefully used, possessed curative properties for certain human ailments.

The Electric Fishes which Light Up the Seas With Unmatched Splendour

These fishes were the earliest electric machines used by man. The light-giving jelly-fish emits a phosphorescent fluid from its tentacles; the electric fish has its batteries in modified muscles. The great armoured fishes are dead and ended, but the electric fish, with its smooth and slimy coat, flourishes in salt water and fresh, and the jelly-fish, synonym for all that is impotent and futile, still peoples the seas in unthinkable millions, and illumines it with unmatched splendour.

We trace a distinct advance toward the higher life when we reach the lung fishes. These, restricted to Australia, to West and Tropical Africa, and to the Amazon region in South America, must clearly have been a sort of trial-trip in the direction of life beyond the waters. These fishes learned to use the swim-bladder as a lung. It was good so far as it went, but it did not go far enough. It did not take the fish out of the water, or at any rate it did not take out all that developed in this direction. For we have the true lung fish to-day, as we have had it ever since Permian times. The device serves to keep the lung fish alive when the river in which it lives dries up, for when drought has come and water gone the fish curls up in the mud, and sleeps till better and wetter days return. The climbing perch, without developing a lung-like organ, has mastered the secret of dry-land

travel, but this is by means of an adaptive trick enabling him to keep his gills well moistened while he scuffles along on his fins over the dusty road that leads from an evaporated pond to one which still holds water. The climbing perch is not so true an air-breather as the lung fish, but he is to be had in remembrance, as, with his rival, he suggests the means by which the first amphibians survived, when low tide first left them, high and horrified, upon dry land.

It is specially interesting that we should have these two fishes, as well as representatives of primitive amphibians and reptiles, still with us. The amphibians, the animals born in water which come ashore to live, are among the most detested of living creatures, yet they are among the most interesting. Here we have the descendants of the first backboned animals with hands and feet, fingers and toes. From such creatures as these grew the gigantic dinosaurs and the monsters of the marshes and the waters of the early world.

A FLYING OPOSSUM

The wing, or flight membrane, of this little Australian "sugar squirrel" is broad, extending from the outermost toe of the fore foot to the ankle of the hind foot

Truly the history of the ages is marvellously told in the natural history of the frog or the toad. From the tiny egg emerges the little sable streak of life with wide-spreading gills fanning in the waters, and the tiny tadpole swims with absurd activity about its petty business with the very action of an industrious minnow. Only the practised eye can tell the young tadpole of a frog from the toad or the newt, so closely does each resemble the other. As the tadpole waxes, as his little hind legs appear and his forelegs follow, as his gills disappear, and finally the real frog's jaws take the place of the lamprey-like mouth, we see clearly how Nature has worked her way through the scale of progress to give us this curious two-legged, two-handed amphibian.

And we wonder, in the spring, what courting-time must have been like in the days before man. The frog, so placid and retiring in the warm days of summer, when most of us are out upon Nature prowls, is in spring the very embodiment of ardour and activity. He is a changed beast under the influence of the reproductive instinct. His voice is terrific, his throat is enlarged, and its colouring altered, so that whereas ordinarily it differs but slightly from the tone of the rest of the under side of the body, now it is livid. The timid beast has suddenly become invincibly bold; he swims with amusing vivacity, restless, consumed with passion; night and day he is at boiling-point. If the old-time giants of the class to which he belongs were proportionately ardent when they wooed, with what cyclonic lovemaking the primeval marshes must have resounded!

AN ANIMAL WHOSE HABITS HAVE CHANGED ITS STRUCTURE

The great ant-eater of South America, a living relative of the giant sloth, is a remarkable example of adaptation to circumstances. Living on ants, this comparatively huge animal has lost all traces of teeth, and has the tiniest hole for a mouth at the end of its elongated skull.

The newt, the salamander, the frog, and the toad remain to remind us by their life stories of animals which were among those first thrust ashore. A still more notable signature by the hand of Time is written for us, however, in the anatomy of the sphenodon of New Zealand, a reptile neither lizard, nor crocodile, nor tortoise, but having links with each. Its head suggests both tortoise and crocodile; so do certain of its ribs. In other respects it is clearly an

THE COLLARED FRUIT-BAT NESTLING ITS YOUNG AS IT HANGS FROM THE BOUGH OF A TREE
The bat spends most of its life, when not flying, hanging by its thumb from a tree. Of all the many ways in which animals have sought escape from their enemies, that of the bat is, perhaps, the most remarkable, for the bats, alone among mammals, have converted their hands into wings, and, without feathers, mastered true flight. They were insectivores, of which moles and hedgehogs are typical examples to-day.

THE TWO-TOED SLOTHS OF SOUTH AMERICA, WHICH ROLL UP LIKE A BALL AS THEY HANG FROM A TREE

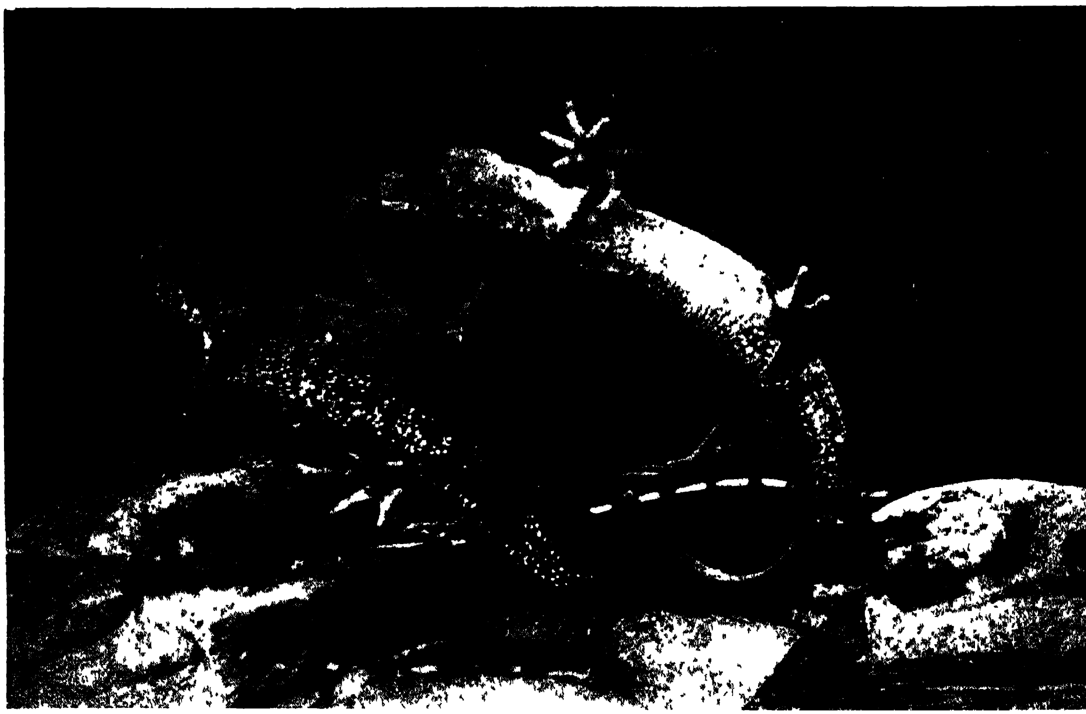
The sloths, when moving or feeding, hang, back downwards, suspended by their hook-like feet and hands. These uncouth creatures move from bough to bough in a lazy, cautious manner, and when sleeping they roll themselves up into a ball resembling the lichen-clad knots of the trees they inhabit. Like the bats, who also see the world mostly as they hang upside down, the sloths are animals of the night.

anticipation of the earliest birds, and of the lowest of the mammals. One of the earliest of reptiles, it has lagged in a backwater of life through unnumbered æons, while from the family of which it is the sole survivor there emerged many important orders totally unlike the original type.

The sphenodon is our oldest "living fossil," preserving for us characteristics which have remained through millions of years unchanged. Not the least interesting of its features is the pineal eye, which in this reptile is more clearly seen than in any other existing animal. Every vertebrate has the remnant of this third eye, but until an examination of the organ in the sphenodon made its purpose clear, this unused organ of vision was regarded by followers of Descartes as the "seat of the soul." We owe the true explanation to the sphenodon.

We call that useless eye which lies buried deep in the brain of the sphenodon a rudimentary eye. It is nothing of the sort. It is a remnant of an eye which once served some necessary purpose. The mere use of the term "rudiment" in zoology is interesting. It recalls the days of Darwin's early manhood, up to which time most naturalists believed that all species had been separately created. Vestiges of organs which had become useless were termed rudiments, the beginnings of organs which would become useful in time.

Quite unconsciously the zoologists of the period were admitting the possibilities of evolution, but they were looking at the matter from the wrong end of the telescope. Examining, say, the two egg-laying mammals, they would find small teeth in the jaws of the young duckbill, and would have to say: "Here is an extraordinary animal which is aiming at dentition. At present it has but a beak, but some day it will have real teeth." Which is, of course, exactly the opposite of the facts. The duckbill and the spiny ant-eater are as precious relics among mammals as the sphenodon is among reptiles. They are the most primitive of mammals, but the changes they undergo in development are sovereign testimony to the fact that they do not represent the original form of the first mammal. They are descendants of animals which had five pairs of teeth in each jaw. The young platypus still has teeth, but these wear down and finally go altogether, and in their place grow up horny ridges, so that the beak of the adult is a very good copy of that of the duck, from which the animal takes its name.



A PAIR OF NEWTS AT HOME—THE MALE AND FEMALE OF THE CRESTED NEWT

Living in water during the breeding season, newts, as a rule, pass the rest of the summer on land, seeking shelter beneath stones and roots, or in holes, wherein they pass the winter asleep. The crested newt is found in Britain, and feeds largely on tadpoles.

But the interesting features of this animal are not limited to its teeth. Its whole life story is enthralling as casting a light upon the past of the mammalian class. The female lays eggs from which the young are hatched, blind, naked, and helpless, round-mouthed, ready to suck the milk ejected from the mother's glands. The secretion of the milk is effected from glands lying at the base of a little, cup-like depression. The platypus is fur-clad like a mole, and has webbed, clawed feet suitable to its life in the water and to its burrowing habits on land, where it makes its nest. It has many points of resemblance to extinct reptiles, the young dependent from birth for sustenance upon its mother. But whether we may safely regard the marsupial pouch as a rudiment or a remnant, there is reason to doubt. Nearly all the animals of Australasia—the home of the egg-laying mammals—are marsupial. With the exception of the duckbill and the echidna, they produce their young alive. That may be, perhaps, overstating the case. The young at birth are hopelessly immature, mere embryos, and have to complete their development in the external pouch, attached to the teats by which they are automatically fed without any voluntary act on the part of the young.

THE DUCK-BILLED PLATYPUS AT HOME—A MAMMAL WHOSE YOUNG ARE BORN FROM EGGS

The duck-billed platypus and its cousin, the echidna, both natives of Australia, are unique as the only mammals whose young are born from eggs. This quaint creature lives in burrows with a tunnel leading into water, where it swims easily by means of its webbed feet. This picture shows male and female.

and the temperature of its blood is much lower than that of the average mammal.

The spiny ant-eater, or echidna, has a very bird-like mouth, but it has a long, rasping, cylindrical tongue, as have all ant-eaters, of which the echidna is one. It lays a single egg, and places it in its marsupial pouch, in which its young, when hatched, is suckled.

Here, in these two animals, after all the ages in which evolution has been at work, we have suggestions of the step by which Nature proceeded from the reptile to the mammal, from the cold-blooded to the warm, from the young hatched from the egg and left to take care of itself from birth, to It was formerly believed that marsupials constituted the ancestral type of mammals, but later investigations encourage the belief that the marsupial is, after all, a degenerate type—that it at one time gave birth to young as well developed as the young of the rest of the mammalia. The naturalist-detective is not able to predict discoveries with the same confidence as the astronomer, but he is looking with high hope to the day when the secrets of certain strata in Africa shall be laid bare. There, perhaps, the history of the mystery will be revealed.

Diet is at times a fairly good guide to the nature and order of an animal, but it is far

from infallible. Seeing that the echidna and the ant-eaters of South America depend almost entirely upon the same form of food, there might be a disposition to group them as belonging to the same order. As a matter of fact, however, the comparative anatomist compels us to recognise that that freakish animal with the huge claws and the long snout, the great ant-eater, has the sloths as his nearest allies. To the same order belong the pangolins and the armadilloes, though some authorities demur to this classification. Differing widely as they do, they are thus grouped because of the remarkable character of their teeth. The distinction is not an enviable one; the members of the order have either no teeth at all, or teeth of rather degenerate structure, lacking both roots and enamel, and in none are the front teeth present. Because of the inefficiency of their teeth they are called the edentata, indicating that they are deprived of teeth.

A RARE TYPE OF ANIMAL ONCE SPREAD OVER THE WORLD

The chevrotains, or mouse-deer, are the sole survivors of animal [illegible] widely spread over the Old World. This African species readily dives

From a photograph of a living specimen obtained by Sir Harry Johnston

Vastly as they differ in form and habit, the members of this group can be traced back, through various fossil forms, to a common ancestry—a striking example of the divergent courses taken by the branches springing from a common stem. There have been monsters in their house, the giant sloth most remarkable of all, but they are a degenerate family. The sloths are driven to the trees, the foliage of which they eat, surveying life as they hang from a branch, barely able to make their way along the ground when necessity compels them to quit the trees, to which they attach themselves by hook-like claws. It is not a little remarkable that while the tunicate puts on a cloak of a sort of vegetable fabric, so the sloth, hanging gloomily in the trees, develops a vegetable growth upon his hair. A minute alga grows luxuriantly in the cracks or flutings of the coarse outer hair, so that the sluggard of the mammalian class appears to be part of the tree in which he passes his melancholy existence.

THE ZEBRA ANTELOPE OF LIBERIA

A rare denizen of Equatorial West Africa, the zebra antelope, sometimes called the banded drinker, is distinguished by its striking colour, its ground colour being golden brown, broken by eight or nine black stripes.

From a drawing by Sir Harry Johnston

The result is a masterpiece of protective coloration, for the sloth assumes a greenish tint exactly matching the foliage upon which he subsists. But it is the expedient of inertia; Nature appears not to be proud of the edentata. They are a dying order. Most of the branches of the family are extinct.

For the rest, while the sloths take to the trees, other members of the order have been compelled to put on armour, to burrow underground, to move stealthily by night; while one, the two-clawed ant-eater, emulates the sloth in hanging back-

downwards from the branches of trees in which it makes its home. Degenerate though they be, these animals are vastly interesting Anything more grotesque or extraordinary than the great ant-eater, living only in South America, with its tube-like mouth, its immense bushy tail, and its huge claws, could not well be conceived, though its distant cousin of the Old World—the aardvark, or Cape ant-eater—with its thin, pig-like snout, its worm-like tongue, its uncouthly fashioned body, equally deserves a place in the long list of Nature's freaks.

In a genus of a higher order we have one of the old-time puzzles - the tapirs. They are to be found (1) in the Malay Peninsula, Sumatra, and Java; and (2) in Central and South America -in these places, and nowhere else. This curious distribution seemed substantial evidence in favour of the theory of distinct creations. But the naturalist-detective has prevailed. He has shown that, though wide seas roll between the homes of the existing types, tapirs were once among the most widely distributed of hoofed mammals. They flourished in England, they inhabited the Arctic Circle, thus proving that the climate of the Far North was once genial, with abundant vegetation. The ancient land connections by which these animals travelled have broken down, shutting them in where we find them. Climatic changes, variation of food supply, and other causes have sufficed to effect the obliteration of the species which remained in that part of America where the tapir is now unknown. Many changes in animal structure have come about since the tapir assumed its present form, but links have been found associating it with the rest of the hoofed mammal family, and one of its ancestors, the palæotherium—extinct wild beast—tapir-like in general outline, possessed features which foreshadowed the horse tribe.

AN UNGAINLY BEAST OF SOUTH AFRICA

Found in South Africa, north of the Orange River, this ungainly and melancholy looking antelope, the brindled gnu, or blue wildebeest, has quite a comic appearance when indulging in characteristic caperings.

The change from warm climate to cold suffices to account for the disappearance of the tapir from England, but a reversal of the process probably robbed us of another beast as strange, the musk-ox. Here is the connecting-link between the sheep and cattle, but nearer acquaintance with the takin, which in turn links the goats and antelopes, induces the belief that it is to this long-sought animal, of which the Zoo has obtained a specimen at last, that the musk-ox has closest affinity. Be that as it may, the musk-ox is one of the most interesting examples of the way in which Nature arms her offspring for their battles with special conditions. She hates waste places, and sends to one the musk-ox, marvellously resembling the sheep in certain particulars, highly specialised for its life upon slippery, ice-covered ground by the presence of gripping-hairs between the hoofs; a cud-chewer, and yet displaying affinities to the non-ruminant. Only in the wildest, dreariest parts of the Arctic regions is this strange compound of designs now to be found, yet the superficial deposits of Norfolk reveal the remains of the musk-ox of our cold and distant past.

If diversity of design distinguishes the musk-ox, confusion of parts is still more pronounced in the gnu. It is an antelope, and has the limbs proper to an antelope. But it has the mane and tail of a horse, the horns of an ox—in structure, though not in

outline—and in general anatomical features it resembles the African buffalo. The make-up of this strange creature might suggest that Nature, trying a variety of structural schemes in as many different animals, decided to see how they blended in one and the same creature. She endowed the gnu with qualities as conflicting as its physical features. Thus, while timorous in the extreme, these creatures are the victims of consuming curiosity; and though they flee like the wind at the first sign of danger, curiosity draws them back, and fright and inquisitiveness conflict while the gnu capers and leaps in the vicinity of the hunter until the fatal bullet puts an end to curiosity.

The Little Animal of Our English Parks Which is Still True to Type

After these examples of extreme development, of the curious results to which evolution leads, we may turn for a moment to the other end of the scale, to view, not, indeed, originals, but as near to originals as we can get, in the chevrotains, the pretty little animals which preserve for us the earliest picture of the deer family. They have been traced back to an ancestry from which all the deer tribe sprang. Whereas the rest of the family have developed in shape and size, adapting themselves to varied climates and conditions—from the far-northern habitat of the elk to the peaceful scenes of the park-deer of England—the little chevrotain remains true to type, an animal without horns, spare of build, little more than a foot high at the shoulder, progressing over the ground on tip-toe with a stiff-jointed gait, placed lowest in the scale of family honours, yet most highly to be reverenced as the most ancient type of deer. In human society the oldest families are the aristocracy, but with the aristocracy of the animal world the newest are the aristocrats; the most highly developed type heads the family tree.

The Story of Evolution as Told by the Antler of the Deer

Nevertheless, though no one would spare the lordly moose, the most magnificent development of the deer tribe, none of us would sacrifice the little chevrotain, reminder of the humble days when all deer were tiny and little specialised.

There is a very interesting chapter in evolution to be read in this contrast between the chevrotain and the elk; and the student may extend it by examination of the antlers in successive years of a growing deer. There we see at once the story of the animal's growth from year to year, but when we know a little more we realise that in the development of antlers year by year, from small and simple to large and branching, there we see also the reproduction of the story of the deer's development from age to age. Each year's condition of the antlers represents an epoch in the history of the deer family. The small antlers developed in the deer's first year stand for the class of antlers carried by the most primitive deer when they had first begun to develop these weapons. The antlers drop off, and are succeeded in the following year by antlers which begin to branch, so marking a corresponding development in the past history of the family. And so the story runs, from one geological period to another, the history of successive epochs retold by each year's development of antlers. But the little chevrotain remains to tell us of the earliest era when deer had not put on antlers at all.

No bird survives to remind us of the first reptile that took unto itself wings and mounted into the air. Certain reptilian characters remain in all birds, but there is no survivor of the leathery winged, featherless creatures which had teeth and talons to aid them in the battle of life.

An Attempt to Reconstruct a Chapter of Evolution

We have, however, a number of so-called flying animals to teach us how reptiles and mammals first began to fly; and the bats, one of the most remarkable and ancient of surviving mammalian orders, flourish in mighty hosts to elaborate the story.

It is not difficult to imagine this chapter of evolution, and we may reconstruct it according to our fancy. The insects had crept out of the water, and, with a rich and varied vegetation to sustain them, waxed and multiplied. After them followed the amphibia, which had learned to dispense with water-breathing gills and to infuse oxygen into their blood by means of atmospheric air. They may have pursued the insects and devoured them. The insects were the first things to fly, and their flight would impel their pursuers to emulate them. The earliest animals contented themselves, no doubt, by pursuit on foot, in and out of the herbage, into the soil, up and down trees. But presently some of them risked the first attempt at flight by launching themselves into the air, and breaking their fall by outspread limbs and distended skin.

Nature is a complaisant parent, permitting her children to try all manner of experiments, and rewarding intelligent

effort. The first result, or the best result, short of true flight, is to be found in the flying lemur, an animal which, without wings, can cover a distance of 120 feet at one swoop.

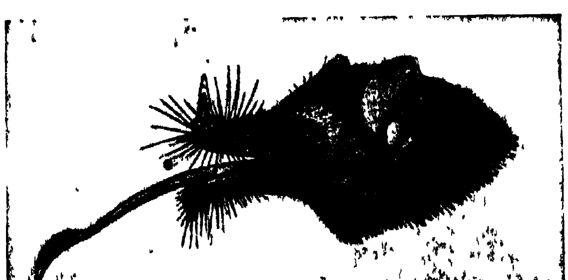
AN AFRICAN FROG AND ITS TADPOLE

This wonderful flight is accomplished by a singular modification of the animal's skin, which, beginning at the throat, provides a collapsible parachute, extending from both sides of the body out to the extremity of all four limbs—short of the claws—and stretching from the hind legs to the tail. The claws serve for climbing; the parachute enables the lemur to plane from a great height in a downward and forward direction, and even, after a dip, to soar upwards, carried by the original impetus. With slight modifications, the same arrangement of the skin serves the flying phalanger of New Guinea and Australia, the flying mouse, or opossum, of the same continent, the flying squirrel of America, the flying frog, and the flying lizard. The so-called flying fish manage their flights of 500 feet at a time, and more, by means of strikingly developed pectoral fins, which they utilise as a parachute. The flying gurnard compasses his excursions above sea-level by much the same means.

THE FLOWER-NOSED BAT OF THE SOLOMON ISLANDS

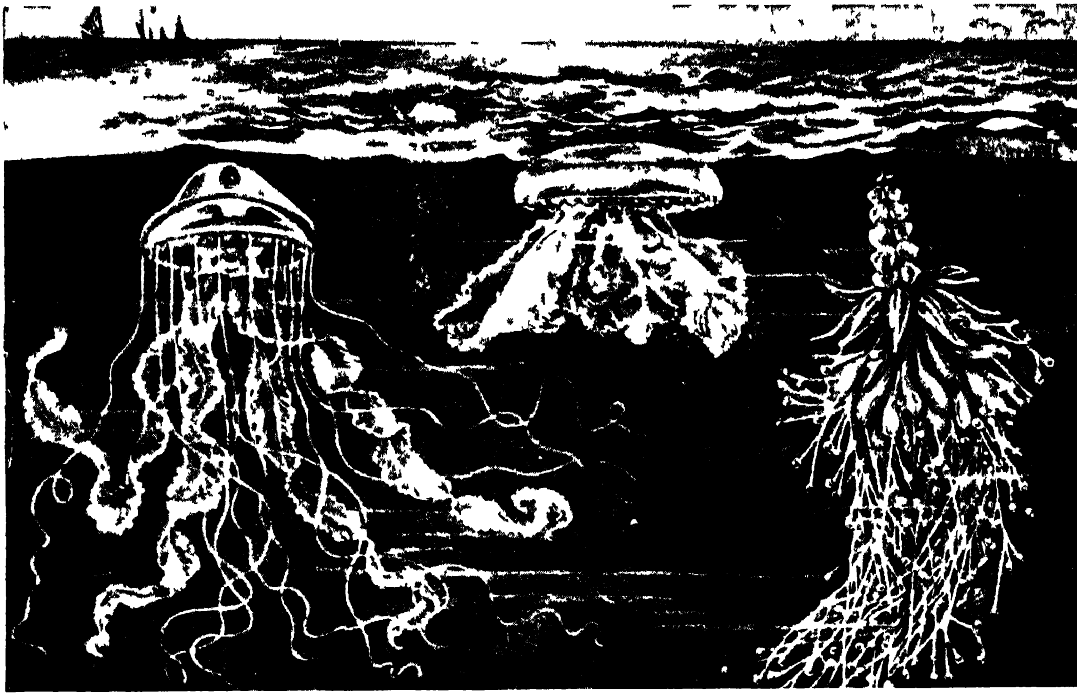
As instruments of flight these extensible folds of skin and abnormally developed fins are primitive implements, but they are as interesting to the student of zoology as true wings. For here, obviously, we get a picture of the way in which flight, the most marvellous of all forms of locomotion, first had its inception. The travels of the so-called flying animals, animals which use a parachute, reproduce the earliest efforts of primitive animals to rise superior to the pull of gravity. Evidently the experiment was not confined to one type, for the flying lemur is very ancient, surviving from a type which emerged before the insect-eaters and the pouched animals were evolved.

FACE OF A FLOWER-NOSED BAT



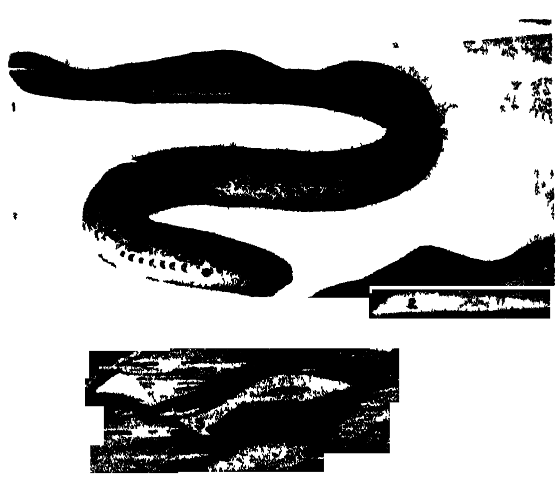
HEAD OF THE LONG-TONGUED VAMPIRE WITH PROTRUDED TONGUE

HEAD OF INDIAN FALSE VAMPIRE BAT

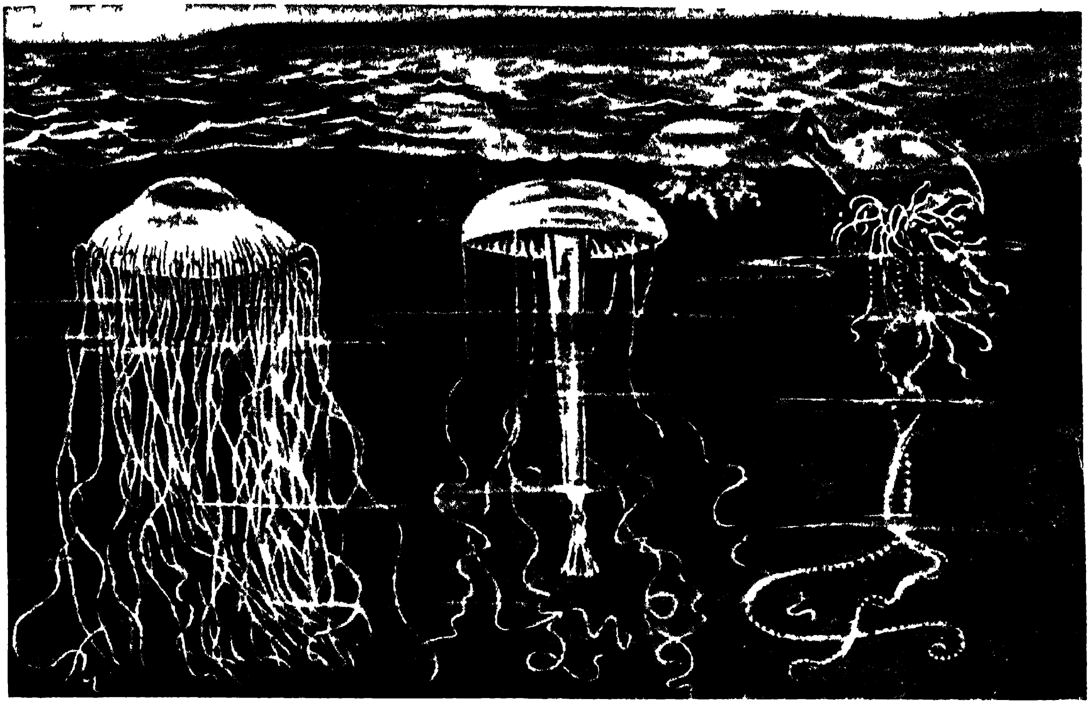


JELLY FISH—THE MARVELLOUS CREATURES LOW DOWN IN THE LADDER

From some insect-eating animal which had begun in this way the first bats sprang. They are of course true fliers, more wonderful fliers than most of us realise until we know of a barbarous experiment once tried to test their powers. Bats which had been rendered sightless were turned loose in a room crossed in many places by threads of cotton. But not a bat collided, either with the threads or with any other article in the room. A day-flying bird will blunder ludicrously if turned into the night; a nocturnal bird is dazed and lost by daylight. Yet these sightless bats flew up and down and across and across this maze without once touching a single obstacle. They have some sense of direction which we do not understand. Still, expert fliers as they are, their wings are not true wings in the sense that a bird's wings are. Bats have enormously extended the bones of the hand and enclosed them in a membrane which continues along the arm and sides of the body, and joins the hind legs—turned with knees outward—to the longish tail. The toes are free, and by these the bat hangs himself up; the two thumbs also are free, and serve as hooks. But the whole equipment is only an extension of the parachute principle, which must once have been on the way to perfection in the flying lemur. The inspiration lay in that extension of the bones of the hand. It gave the bat an advantage over all other living creatures save the birds. Well has the bat profited by his advantages. Few of us realise how numerous these flying mammals are. Bats are relatively few, not, indeed, in individuals, but in number of species, in Great Britain, but they teem in warmer climates. There are close upon eight hundred known species.

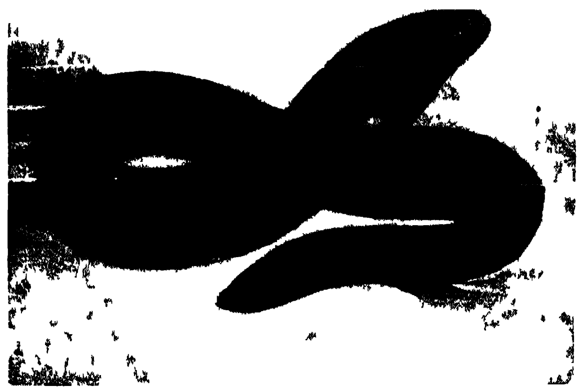


FISH-LIKE CREATURES WITHOUT LIMBS
(1) Sea lamprey, (2) River lampern, (3) Planer's lampern



OF LIFE WHICH ARE MAINLY WATER HELD TOGETHER IN A SORT OF WEB

with as great diversity of form and feature as is found in the whole of animal creation. They are divided into two classes, the insect eaters, which are by far the more numerous, and the fruit eaters. The latter include the flying foxes, great bats with a wing spread of from four to five feet, which are so abundant in India as to cause serious damage to cultivated crops. But there is a third class, the bloodsuckers, the true vampires, which, descending with fanning wings at dead of night upon a sleeping man or animal, shave away the skin with their razor-like teeth, then draw the blood until gorged. This bat has its apologists, but the fact is that the stomach of the vampire is simply an elongated tube, adapted only to the reception of blood and not to a solid diet.



THE FIRST ELECTRIC MACHINE: THE ELECTRIC EEL
A discharge from which is powerful enough to stun a man

With the bats we leave our survey of the evolutionary processes evidenced before our eyes. This sketch is necessarily casual and haphazard, but sufficient examples have been cited to prove that the pageant of life before us is not composed of animals of one dead level of age and attainment. Among some of the lowliest forms of life we find forms most to be pondered over, those living mile-stones which show us the route by which the rest have come, and with them sharing the same area, often the same food, the same risks and vicissitudes, are the highest yet along the same line of progress. The day is coming when many of these links will for ever have been snapped. Civilisation, with sanguinary zeal — though tempered a little with consideration in these latter days — is stamping out wild life wherever she sets her foot. It is well that we should glean while we may something of the romance and wonder that still remain to us in the lives and lineaments of such wild creatures as still survive.

PROBABLY ARBOREAL—PICTURED BY R. L. S.

The first men were in all probability arboreal; they sought refuge in the tops of trees from wilder creatures. The imagination of Robert Louis Stevenson pictured the first man as "a certain low-browed, hairy gentleman, at first a percher in the trees," whose "old, wild, tree-top blood" runs through all our veins"; and science has little to contradict in the imagination of the novelist.

THE MAN IN THE TREE-TOPS

What we Know and what we can Imagine about Robert Louis Stevenson's "Probably Arboreal"

WHERE, WHEN, & HOW CAME THE FIRST MAN?

"THERE is a certain critic, not indeed of execution but of matter, whom I dare be known to set before the best. A certain low-browed, hairy gentleman, at first a percher in the forks of trees, next (as they relate) a dweller in caves, and whom I think I see squatting in cave mouths on a pleasant afternoon to munch his berries—his wife, that accomplished lady, squatting by his side; his name I never heard, but he is often described as Probably Arboreal, which may serve for recognition. Each has his own tree of ancestors, but at the top of all sits Probably Arboreal; in all our veins there run some minims of his old, wild, tree-top blood; our civilised nerves still tingle with his rude terrors and pleasures; and to that which would have moved our common ancestors all must obediently thrill."

So wrote Robert Louis Stevenson, in "Memories and Portraits," and the scientific writer may be grateful for such a passage, which is probably quite accurate in substance, and expresses more than strict science can hope to essay.

The first men, or the first creatures that were more than apes, were "Probably Arboreal," but made adventure upon the ground. We know what enemies, snakes especially, they had to fear, and how their remote descendants share that fear still. Other evidence of our arboreal descent is very various. New-born babies have been found to possess an incredible power of grasping such objects as boughs of trees, and supporting themselves thereby, which they soon lose, and which none can emulate in later years. In the lower types of mankind the arms and the shoulders are much more highly developed than the legs, and the length of the arms is greater in proportion to the length of the body, just as we find in the arboreal apes. The foot of man is a kind of compromise. It is far from being perfectly adapted to the ground, for it is most inadequately protected, and civilised man has always had to provide artificial protection for it, and has always paid the price of corns and distortion of joints in consequence. Yet his foot has lost its power of grasping, and man is certainly not four-handed. The anatomists report, however, that the sole of his foot contains four distinct layers of complicated muscles, most of which serve no present purpose, but which are quite evidently survivals from the time when the organ was used for grasping. Boys still love to climb trees, and have no small natural skill, and a great deal of natural at-homeness there, but one has only to watch them to realise how much the lower limbs have changed since they were suitable for that purpose. Yet the foot muscles evolved for that purpose significantly remain.

"Probably Arboreal" was no doubt an athlete, if we may judge at all by modern gibbons, some of which can throw themselves as much as forty feet from the branch of one tree to catch the branch of another. At the same time, we must remember that the new use of the legs for upright progression involved their strengthening in bone and in muscle, and the arms had to lose something by way of compensation. Man's arm boasts a muscle with two "heads," or places of origin, which is accordingly called his "biceps," but the "biceps" of the modern agile gibbon is really a "quadriceps," for it has no less than four heads. Man is therefore not justified, historically, in attempting to recover the arm-power of his remote ancestors, who, indeed, mainly ran to arm, and had exceedingly light and slender bodies to carry.

Our modern controversies on hygiene and habit add interest to the available evidence as to the habits of the very first men. It

must be admitted that they were certainly vegetarians. Their diet must have consisted chiefly of nuts and fruit. The young were, of course, fed with their mother's milk, and this feeding was very prolonged. Strict vegetarianism was never the practice of the mammalian baby, and never can be. But the adults were certainly vegetarian; and we must disabuse ourselves of the idea that they were savage, club-armed creatures resembling the pictures of the gorilla.

The Birds' Eggs that may have Varied the Vegetarian Diet of our First Ancestors

Like vegetarians in general, our first ancestors must have been of a different temper; not aggressive, probably timid, though light-hearted enough when free from danger in their tree-tops, and doing no more harm to other animals than may perhaps have been accomplished by bird-nesting. Birds' eggs would be welcome diet, and would be the only probable exception to their primitive vegetarianism. Boys, whom we call "monkeys" without entire injustice, climb trees for birds' eggs still.

It need hardly be noted that the teeth of apes and of man are fundamentally distinct from the carnivorous type, but are excellently suited for nuts and fruit, as are man's fingers. Visitors privileged to feed the anthropoids at the Zoo to-day will agree that they eat nuts and fruit in a very human way, or perhaps we may say that we eat nuts and fruit, with fingers and teeth, in a very ape-like way.

We are not entitled to note these facts as conclusive in the controversy regarding man's diet. They are important and highly instructive, but it must be remembered that man is man, not "Probably Arboreal," that his body and his habits are now profoundly modified; and there is a possible argument, on the other side, to the effect that coming down to the ground, with the opportunities it offered for more concentrated and stimulating fare, such as small animals would provide, made all the difference between the ape and incipient man.

The Ancestor of us All who May have been no Bigger than a Child

That argument is probably unsound, but it has to be met; and the wisest course would be for us to decide these dietetic questions on their own merits without reference to evolutionary speculation. Otherwise it would not really be difficult to argue that man should be all manner of inhuman things. This caution applies equally to the athleticism and to the diet of "Probably Arboreal."

The modern gibbon is a tiny animal; and just as the modern horse is descended from a pig-like ancestor, so man is doubtless descended from an ancestor no bigger than, say, a two or three year old child. An arboreal animal must imperatively keep down its weight if it is safely to keep up its body. Those descendants of "Probably Arboreal" who have taken to the ground have lost the necessity for this small size, and accordingly we find the gorilla, which may be five feet six inches high, and man.

These two forms are giants in comparison with their ancestors. The fact is of great interest in more ways than one. Coming down to the ground enabled the first man to grow in size and strength of body and legs, as distinguished from the strength of arm which was so essential in the trees. But it has also been associated with a notable change in the span of life. Longevity has long been an obscure subject, and much comparison of the different forms of animal life, even as lately as the work of Metchnikoff, has left it still obscure though less so. But one generalisation may perhaps be permitted here.

The Great Advantages of Being a Giant

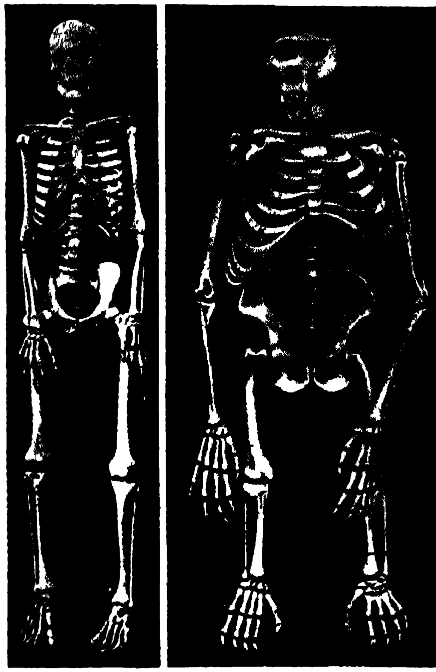
Comparing related forms, say man and monkeys, small birds and large birds, small tortoises and large turtles, increase in size goes with an increased span of life—longevity comes in with giantism. The underlying explanation of this fact is yet to be found, but the fact itself interests us.

Man is the giant ape, so far as his body is concerned; and accordingly his span of life may run to a century, where twenty years, perhaps, would have been a great age for one of his small ancestors. The gigantic size of man—for he is definitely a giant when looked at historically—has another great advantage in that it enables him to maintain his bodily temperature with much greater ease than is possible for a small animal, which has so large a surface in proportion to its mass, and cools so much more rapidly. It cannot be believed that a denuded tropical animal of the size of the gibbon could have survived and thrived in temperate zones as man has survived.

When, therefore, the modern athlete envies the astonishing skill and capacity of a couple of gibbons having a game, he should remember that he is a giant, relatively to them, that this is greatly to his gain on the whole, that the price he has paid for it in diminished agility and relative

arm power is a small one, and that to attempt to equal the gibbon in this respect is to go back upon his distinctive physical humanity. He has enormous advantages of his own in other respects, and he should remember that he is human largely because his arms are no longer used for locomotion, but for higher purposes, and he should be grateful for the longevity which he has gained, so that he is in his physical prime at twice the age of an aged gibbon.

Readers in this country should be interested to know that to Dr. Arthur Keith, Conservator of the Museum of the Royal College of Surgeons, we owe much of our modern understanding of this problem, largely due to his original study of the higher apes. That museum, by far the finest of its kind in the world, affords splendid opportunities for those who are interested in this subject. It is right that not all the honour should go to the well-known foreign anatomists in these latest developments of the theory of Darwin and Spencer and Huxley. In the foregoing there is much, nowhere to be found in print, which we owe to Dr. Keith's recent lectures on the subject, and to which grateful acknowledgment is here made.

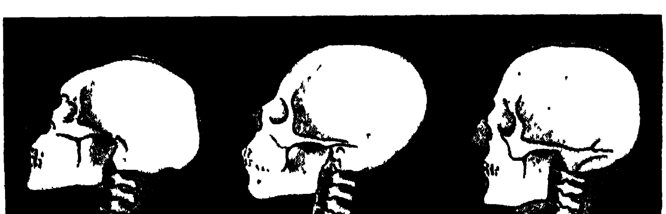


THE SKELETON OF AN AVERAGE MAN AND A LARGE GORILLA

Man is a giant compared with the apes, with the exception of the monster gorilla which most nearly resembles him in size. But the features of the gorilla clearly shown here—the enormous jaws and tusk-like teeth, the gigantic pelvis and the thumb-like big toes, the small brain, the length of arm—emphasise the kinship of this extraordinary creature with the lower animals.

Now we have to consider the next stage in the habits of the new being. We may suppose that at first it stayed near the trees which spelt safety, but gradually it would gain confidence and trust itself to the ground, as we see the young gibbons, when at last they are satisfied as to the absence of snakes, do at the Zoo to-day. But there is no really safe way with snakes but to avoid them, and one must avoid the places where they live. Thus we may legitimately surmise that, once "Probably Arboreal" went so far as to leave his tree and try life upon the ground, he was encouraged to go a little farther, and get out into the open, where snakes, if they were there, could be seen, and would be less numerous. So far as the evidence goes, all we can say is that, at some stage or other, by some means or other, we find very early men living in caves.

It must be remembered that this creature is living from the first by its wits. That is the mark of man from the beginning until to-day. With whatever difficulty, we must disabuse our minds of the picture of the open-mouthed gorilla advancing upon his enemy with a club. Our primitive ancestors were small; they were exceedingly agile, no doubt, but they must have been far from steady on their legs at first, and they were certainly not ferocious. Their aboriginal habit of life was the safety of trees, the shade and the protection they afforded from sun and rain, and from animal foes. If we begin with these ideas, we shall not find it difficult to understand that these lately arboreal creatures, fearful of snakes and accustomed to some degree of protection from all manner of injury, should take to living in caves. Be it never forgotten that we are dealing with a creature which was remarkably intelligent and original and curious, which could no more refrain from entering a hole in a cliff, once seen, than a modern boy can, and which would very quickly find that such a hole had some very desirable properties as a place of residence. This is a creature,



HOW THE SKULL OF MAN HAS MADE ROOM FOR THE BRAIN

These three skulls of (1) an Australian native, (2) a negro, and (3) a European show how the human skull has been gradually pushed forward by the brain.

too, which has exceedingly serviceable hands: and these hands, formerly used both for locomotion and for other purposes, are now entirely freed from locomotion, and simply long to use their liberty by doing more than ever in the way of picking up and touching, and examining, and even digging and constructing—just in the fashion for which children are daily reproved in modern times.

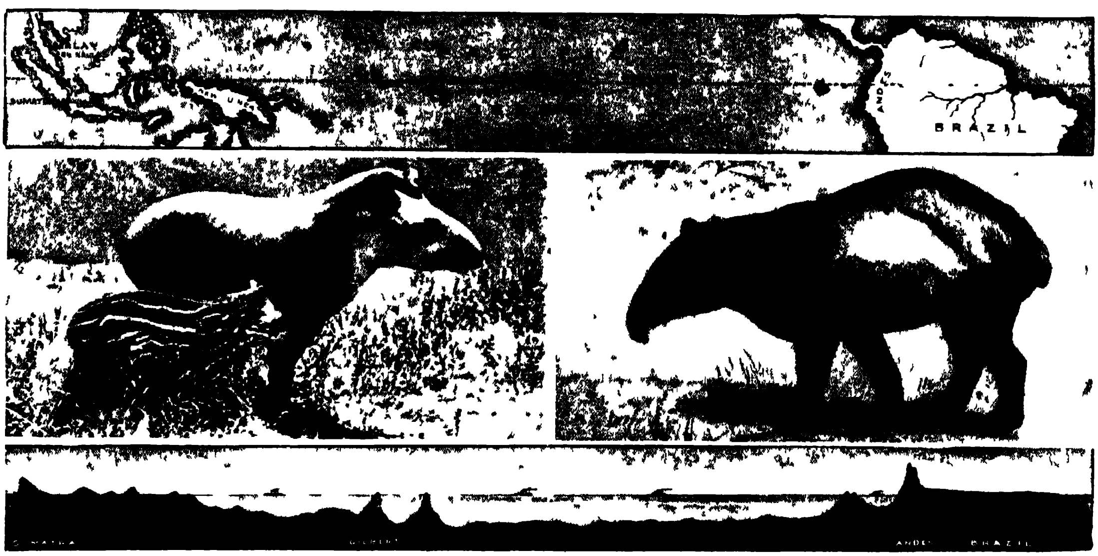
To these characters of body and of intelligence, notably of insatiable curiosity—which reaches such heights in the modern man of science—we must add those of imitation, and the power of learning by experience, which we see in modern apes, and which are extraordinarily developed in ourselves. The common description of man's first parents as solitary animals, or as living in small families, after the fashion, or alleged fashion, of the gorilla, is probably quite erroneous. It is much more likely that our ancestors were decidedly, or, at the least, potentially, social and gregarious, as we should expect in creatures so imitative and suggestible. Hence, we can begin to see how the observations and successful experiments of one or two "born leaders" would soon modify and advance the practice of the first men as of their latest representatives. The original minds are wanted first, and then the receptive and imitative faculty in the crowd.

Whatever the sequence and manner of events, certainly man did somehow come into being from an ape-like and arboreal ancestor; and when we have attempted to trace the possible manner of this evolution, so far as the habits of the creatures are concerned, we may pass on to face three great questions which evidently remain.

Where did all this occur? When did it occur? How did it occur?

The first two of these problems, the birthplace of man and the antiquity of man, are of old standing, and have reached some degree of solution. As for the problem of the origin of man in the sense in which Darwin wrote of the origin of species, that question also has reached a new phase in our own day.

The birthplace of man, all are agreed, is in the Old World. Like the light and all other things, he came from the east, and westward the course of his empire and the light of his mind have taken their way. Man in the New World is clearly an immigrant, not a native. We do not find fossil remains of man or of anthropoid apes there, though the New World abounds in noble fossils of a thousand other kinds. There are no anthropoid apes there now, nor ever were, but only tailed monkeys. The aboriginal inhabitants of the New World appear to have reached it, we think, by travelling from North-Eastern Asia, and entering the New World from the north. Land may have been continuous in those days between the continents. On this theory we might expect all the aboriginal and native—but



THE QUAINT LITTLE ANIMALS THAT CROSSED THE PACIFIC BEFORE MAN WALKED THE EARTH

The two types of tapirs shown above, both from the same original stock, are found to-day in Malay and the United States of America. They must have crossed the Pacific Ocean, a distance of about 5000 miles, as shown by this map; yet the way they must have gone is now deep sea, as shown in this section of the Pacific. How did the tapirs cross? There is no doubt that the answer is that they crossed by land which then connected the American and Australian continents.

not indigenous—men of the New World to be yellow-skinned and to partake of the characteristics of the Mongol. That is, indeed, what we find, not only in details of anatomy, but also in habits and culture. The first settlers in America were yellow; and now the problem is whether any more yellow men are to enter the continent which their remote forefathers discovered!

We turn to the Old World, then, for the birthplace of man, and in the Old World certainly to Asia, where we found the "ape-man," and where we find the gibbons and the orangs to-day. But there are anthropoids in Africa also, the chimpanzee and the gorilla, which are found nowhere else; and there are very primitive human beings in Africa. Thus it may be suggested that man had more than one birthplace. Perhaps one kind of man, and that superior, was born in Asia, and another, inferior, in Africa.

This view of the multiple origin of man is not now held by high authority. All the evidence is against it. Far more probable, not to say proved, is the view that certain lowly types of man, who suggest a beginning in the places where we find them, are degenerate, and represent ancestors of higher type who settled there. This is one of the great controversies not to be settled in a paragraph, but apparently we have no choice but to believe in the single origin of the human species, and that origin must have taken place in Asia. Needless to say, any further suggestion must be highly speculative. The discovery of the "ape-man" in Java, and the existence of anthropoid apes in the islands of that neighbourhood, do suggest a more definite site. But at this point we plainly have to reckon with geology, and what it may teach us as to the past. For we are speaking of very ancient times, and no one can suppose that the configuration of land and sea was then what we find to-day. There is some reason to suppose that such islands as Java and Sumatra and Borneo represent the remains of a now submerged continent. It thus may be that the true birthplace of man is now an ocean bed.

MAN HAS LOST THE STRENGTH AND AGILITY OF LOWER ANIMALS, BUT HIS HANDS HAVE GIVEN HIM MASTERY OVER ALL CREATED THINGS.

The next question, as to the antiquity of man, is no less interesting. Of course, we here depend again upon geology. We trace back human records as far as possible, say as far as the "ape-man," and we compare with these and the levels at which they are found the corresponding facts regarding the fossil-apes. But when this is done we are bound to refer to the geologist for his estimates of the antiquity of these various deposits in which man and his congeners have left their first marks.

The estimates vary from time to time, but they always vary in the same direction,

which is that of extension. Geology has discovered in radium and radio-activity, for instance, a series of facts which lengthen nearly all its estimates; and at the same time our fossils of man and apes continue to be found at deeper levels. Not long ago one-third of a million years was a figure which gained credence on the grounds then available, and indeed that seemed a long time; but it is little enough when compared with modern reckonings of the antiquity of the earth's crust and the life it supports.

The Birthday of the First Man—Was it Six Million Years Ago?

Latterly Dr. Keith and other students have rejected even this figure as inadequate, and Dr. Keith has suggested something like six million years as representing the antiquity of man. A more accurate statement would be that this figure represents the date at which we may suppose the ancestors of man, and man alone, to have split off from the common stock which is now also represented by the anthropoid apes. Whether any man would admit the title to the name, if claimed by his supposed ancestor of six million years ago, is another question.

The answer to it is involved in the last of our three questions—*how* came man?

We have studied man's forerunners, and the probabilities of the sequence between them and him, and we have clearly seen that he has allies in the animal world of the present and of the past. But the fact remains that the abyss between man and these creatures is wide and profound.

When the lowest forms of man have been observed, and the highest forms of animals, and when the utmost allowance is made for the advantages of training and society in the one case and their absence in the other, and when all the resemblances between the human and the anthropoid brain, the human and the anthropoid habit of mind, have been generously estimated, the *how* of man's origin is scarcely one whit less formidable than ever

The Formidable Mystery of How Man Came into the World

He still is seen to be unique and inimitable, and we are fain to grasp at the explanation of a special creative interposition. Even to-day the illustrious Nestor of Evolution, Dr. Alfred Russel Wallace, to whom we owe, in part, the theory of natural selection, finds it impossible to account for man's mind except on some such theory, whatever may be the case as regards his body.

If a natural explanation is alone to satisfy us, we must choose, it now seems clear, between two. The choice need not be determined by any time advantage belonging to one or other, for modern geology, and the records of fossils, allow us an unimaginable space of time; and if we are offered a theory which demands enormous ages, it may have them. One of the theories does make this demand; and the time has now come when we may venture to call it the classical theory, for it depends upon the unaided application of the Darwin-Wallace doctrine to the human case. That doctrine asserts that new species come into being very gradually through the inheritance and slow accumulation of minute variations in many successive generations, such variations being chosen by "natural selection" because they favour the survival of the individual and the race. In the case of man, we naturally think of the brain, which matters everything. We are to suppose that, in the case of this creature, living by his wits, those wits would be stringently chosen by natural selection. The "brainiest" would survive and leave children, and thus, at last, our ancestor would become human. Granting that there is an enormous distance to traverse between the two, geology will allow enormous periods of time for the process.

Did Man Come About by Slow Degrees or by a Sudden Change?

Here we shall not presume to choose between this theory and the newer one; our present business is to state both fairly. The newer one takes regard of the recent evidence, supplied by the followers of Mendel and others, which suggests that, contrary to the view of Darwin, species arise more commonly, if not always, by quite abrupt changes in type. This view would not require anything like so much time as the other. According to it, a comparatively small number of abrupt changes in the brain might occur, subject to the laws of what is called "variation," and these changes, being favourable, would be spared by natural selection. They would resemble the production of such a "sport" as a nectarine by a peach-tree. Thus we should regard man, not, indeed, as "a sport of the higher apes," but as a sport from the original stock of the higher apes and of man. The production of sudden varieties, potentially human, among ape-like forms, is consonant with all the known facts of other species, and may have thus occurred. Natural selection would then favour the survival of such "sports," because of the survival value of superior brains and superior instincts.

MICHAEL ANGELO'S THINKING MAN

It may possibly have taken six million years, some authorities think, for human life to reach the summit on which man now stands—six million years, that, is to bridge the gulf between the far-away man in the tree-tops and the thinking man whom Michael Angelo so finely embodied in this statue of Lorenzo de Medici.

THE TERRIBLE PLAGUE OF ROME WHICH MISLED MANKIND FOR GENERATIONS

The popular fallacy that night air is bad air is clearly traceable to the plague of Rome—malaria, or bad air. Because this fever was caught at night, it was thought to be due to bad night air, but it is now known to be caused by a mosquito which feeds in the air at night, and not by anything in night air, which is, of course, the purest air of all. This picture is from a famous painting of malarial plague by M. Delaunay.

BREATHING LIFE AND DEATH

The Truth and Some Illusions about Fresh Air and the Life of the Open

WHAT A CHANGE OF AIR REALLY MEANS

On every ground we should begin our statement of the demands of health by discussing the need of air. It is the most urgent of all vital needs; the reader will never reach the end of this paragraph, or start another, unless he breathes an atmosphere which will sustain his life. Further, air does not receive its due in discussions on health. Most people's interest in health questions concentrates upon diet. As for those who purvey health, or its means, they are bound to lay stress chiefly upon the special foods or drugs they sell, or upon their special methods of "physical culture." The food may be eaten, or the dumb-bells swung, in an atmosphere which does fifty times the harm that they can do good, but no one minds. Unfortunately from our point of view, the air is colourless, nor are there any colour differences between pure air and foul air; and "what the eye doesn't see, the heart doesn't grieve for."

But for the hygienist, who has no concern whatever but to give the advice which most promotes health, the question of air is paramount. Though, in large degree, air can be had for nothing, the hygienist is just as interested as if it had been captured by a group of capitalists, and the various qualities had to be paid for at the market price. In those conditions, in the introduction of the monetary issue, everyone would agree that the question of air was almost the first and last so far as health is concerned. Here we must make a great effort, and try to get up an interest in air on its own merits, though it is not on view, is not for sale, and though the great majority of people can have all they need for the asking.

Another obstacle to the proper appreciation of this question is that it is not really controversial. If it could be made a party question it would attract people, but on the whole we agree about air. People invent "fasting cures," but they do not invent suffocation cures. The need of air is beyond question; and public sentiment in this country, though by no means upon the Continent, is wholly in favour of fresh air. The most determined non-ventilator, who spends his life shutting windows, and to whom the breath of heaven is miasma and abomination, will pronounce himself an enthusiastic believer in fresh air. Only, he does not like "draughts." Similarly, we all say we like music, though 90 per cent. of us want to talk during the second half-minute of any real music. Public opinion is in favour of air and music; and we conform thereto.

One of the purposes of this chapter will be to show that the man who manifests his love of fresh air by spending his time in excluding it from his precincts does himself and others great harm; and that the difference between lip-service and nostril-service to fresh air is all the difference in the world. It is immensely worth while to pay the real homage, which is not with the open mouth of protestation, but with the open nostrils of inhalation. Here the hygienist does not require to stand up against public opinion and common practice, as in the case of not a few popular habits. He has the easier task of showing how public opinion may really get what it believes in, and of warning it against imitations.

It might seem to be the only proper fashion in which to start that we should make a tabular statement of the differences between pure air on the one hand, and the many kinds of foul air on the other. Chemists have analysed many kinds of air, and it is possible to state the composition of city air and country air, mountain

and sea air, day and night air, "underground" air, sewer air, average bedroom air, and so forth, with much accuracy. Many pages could be taken up with the statement and comparison of these differences be ween pure air and foul.

But the remarkable fact, which has baffled most commentators, is that the differences in composition which the chemist describes seem ridiculously inadequate to account for the differences which the doctor sees in people who breathe these different kinds of air. The doctor knows that in certain kinds of air people die, and in others they live. He reports to the chemist and asks for comparative analyses, and the chemist reports back again that the percentage of oxygen or of moisture is a fractional point higher in the one case and lower in the other. Either we must revise our notions of this subject altogether, and find some fact of health and ill-health which we have hitherto forgotten, or we must suppose that the chemist, though he can measure some of the things in the air, is somehow unable to measure, or even to discover, the most important of all.

How the Mosquito which Feeds by Night has Misled Popular Belief

It is the writer's belief that the chemist is not at all to blame, and that the fault lies with the doctors, who have forgotten, in this connection, what they have themselves discovered and really know so well. If we put together the doctors' discovery and the chemists' analyses we shall have the science of this subject in our hands. The key to it is to be found in the remarkable history of the disease called malaria, or "bad air."

This is not the place for a systematic account of malaria. We can learn all we need if we simply know that this disease, for ages attributed to the breathing of "mal' aria," or "bad air," is now known to be due to invasion of the blood by a minute animal parasite, which is inserted by the bite of the female of a particular kind of mosquitoes. The mosquito begins to feed at nightfall, and those who expose themselves to the "dangerous night air" are thus liable to contract malaria, the bad-air disease.

At one stroke, therefore, modern discovery upsets the oldest and apparently most clearly evidenced of beliefs. The difference between the day air and the night air which produces malaria is that the night air is inhabited by a particular mosquito. We must restate all our old beliefs.

It is probably safe to assert that the habits of this mosquito account for the almost universal superstition about night air. The chemist is entirely at a loss—and naturally so—when he is expected to find any objection to night air, so far as its composition is concerned. On the contrary, everything he reports is in its favour. It contains a less proportion of carbonic acid gas, which does not sustain human life, but is the most important of its waste products. It contains a slightly higher proportion of oxygen, by which we live.

The Destruction of the Old Superstition about Night Air

These differences chiefly depend upon the fact that there is much less combustion, by fires and furnaces, going on at night, so that carbonic acid gas, the chief product of combustion, is therefore added to the air in less quantity than in the daytime. Still more to the advantage of night air in towns is the fact that it is very much less dusty, owing to the diminution of traffic. Compared with ordinary day air, night air may almost be said to be filtered of the solid impurities which we call dust, but which include under that term not only genuine dust, but also a multitude of microbes and their spores, adhering to mere dust and blown about with it for us to breathe.

All along the line, then, night air scores, which is none the less satisfactory, seeing that one has to breathe during the night, and all air at night is night air. And the universal superstition is traced to the habits of a female mosquito. There may have been other elements in it, such as the more superstitious fear of darkness, or of moonlight or starlight, or ghosts, or what not, but there can be little doubt that it is the mosquito which is responsible for the fear of night air—a fear which the prevalence of malaria has so entirely justified.

The Infection that Lies in Night Air in Malarial Countries

It now behoves us, with this recent revelation in our minds, to look again at the whole question of air, and the differences between the different kinds of air. We have found that, so far as chemistry and the filter can show, night air is far superior to day air, but exposure to it, over a wide area of the earth, means *exposure to infection.*

After many years' attention to this subject, and much and often-repeated examination of the evidence, the present writer is satisfied that the hygienic differences between different kinds of air depend far more

ONE OF THE CHIEF ENEMIES OF HEALTH

THE TONGUE OF A HOUSE-FLY, THE ONLY AERIAL INSECT WHICH CARRIES INFECTION IN GREAT BRITAIN

One of the worst enemies of health in the British Isles is the common fly, which carries infection and spreads disease in all manner of unexpected places. This enormous magnification of the tongue of a fly was made for Popular Science by Mr. J. J. Ward.

upon what they mean in the way of infection than upon anything else. All over the malarial parts of the earth, the best kind of air—in itself—is the worst, because it means exposure to infection. And since the broad difference between health and disease is most often due to the difference between not-infection and infection, we may guess that the observed facts of fresh and foul air, city and country air, and so forth, in our part of the world, are due to differences in exposure to infection far more than to anything else.

The Air that is most to be Feared in the British Isles

Broadly speaking, the open air is the safe air from this point of view. But, of course, if the open air carries aerial insects that distribute microbes or such parasites as that of malaria, the safe air is the closed air. The risk of infection decides the question. In this part of the world we preach the value of open air; and in the tropics we preach that the open air is dangerous, especially at night. There is no contradiction. In the tropics the open air is the infected air, so far as the chief tropical diseases are concerned. Here it is the closed air that is infected.

We may now consider only our own needs in this country. We have mosquitoes, but they do not convey malaria. So far as can be discovered, no *aerial* insects convey infection in this country, with the notable exception of the domestic fly, but that is domestic, *not* an open-air insect, and it therefore adds point to our argument. If we need not fear aerial insects, carrying microbes with which to inoculate us, then the open air spells safety for us without qualification, as well by day as by night. And we shall not be astonished to discover that enclosed air is most to be feared, *not*, as doctors have too long assumed, because of its dangerous chemical composition, but because of the microbes it harbours.

The Sunlight which is Fatal to all Forms of Parasite Life

Dangerous microbes can flourish in the open air, but they must take the precaution of being safely housed inside the body of some insect. If not so housed, they cannot flourish in the open air. It means too much oxygen for their tastes, too much movement—whereas what they like is to find suitable stuff to prey upon, and to stay there—and, above all, it means exposure to direct sunlight, which is fatal, rapidly and invariably, to all forms of parasite life, microbe or any other. The whole nature of any kind of parasite is to creep away from the sun and the air, into the darkness and the warmth of the unfortunate body which it has marked for its prey.

Microbes have no wings, and cannot fly; and all the old views about air-borne infection, in which the public still believes, and which were taught to medical students less than a decade ago, must be abandoned. What we have so long called air-borne infection is almost always, if not always, insect-borne or dust-borne. As for infected dust, which is a real danger, one grain of it in a room is more to be feared than a thousand grains out of doors, for out of doors the light and the ever-exposure to moving oxygen rapidly destroy it, whereas indoors, under cover of the darkness, it may harbour dangerous forms of life for months or years.

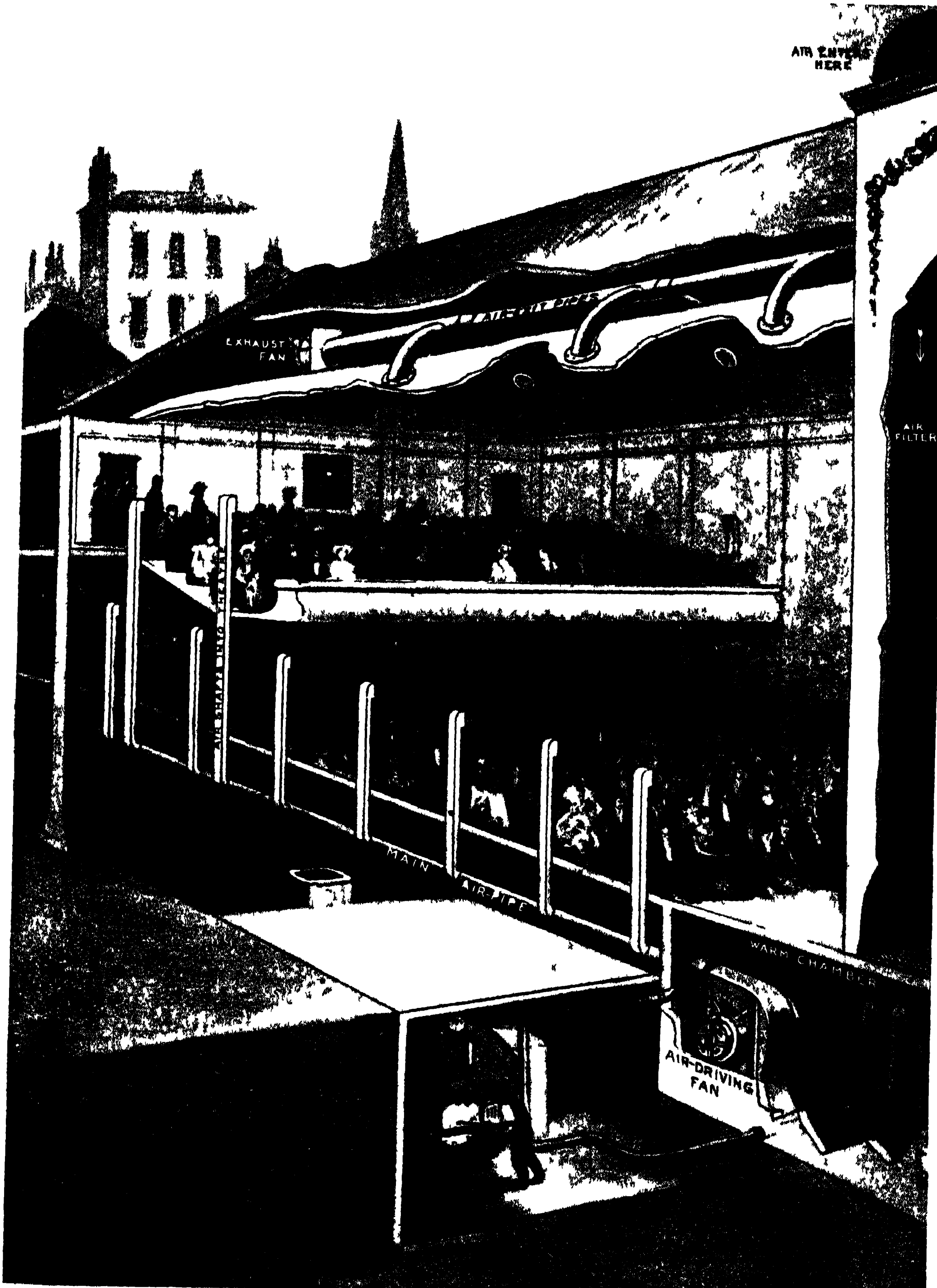
A celebrated student of disease has lately prepared the way for an entire revision of public and professional opinion regarding fresh air. He has asked why fresh air should be credited with such unique virtues in the case of consumption. Why not in other diseases, if it be simply that fresh air strengthens resistance, and enables the patient to throw off the disease? Why should not this apply to all cases where the patient requires more resistance to throw off any disease from which he is suffering?

The Microbe of Consumption which Dies in the Open Air

These questions, lately asked by Sir Almroth Wright, have not yet been satisfactorily answered on the old lines, and they never will be. But the answer to them is quite clear to the expert students of consumption, and of all the other infections that occur and are spread through the breath. The sanatorium for consumption has its own invaluable use in isolating infectious persons, and thus protecting other people, and it would have this use if it did nothing else.

But it does much else. It very often cures the patient, and almost always it greatly prolongs his life. The chief reason is that the open-air structure of the sanatorium, and the open-air life there, are death to the microbes of consumption; and therefore the patients, who may be quite able to recover from the infection they already have, but could not recover from repeated doses of it, are free to get well. There are no new microbes to inhale; and very likely the old ones, already inhaled, can be dealt with by the patient's defences, if they are not reinforced. In former days, patients often recovered when they were sent on long sea-voyages. It was not the sea air that cured them, but the absence of microbes from sea-air. As for more advanced cases, in which

THE AIR OF A PUBLIC BUILDING



THE WAY IN WHICH A CINEMATOGRAPH THEATRE IS VENTILATED

The development of the cinematograph theatre, open frequently all day, would be a great danger if the greatest care were not taken to maintain a pure air-supply in these places. This section of one of these buildings shows how the air enters at the top, flows down an enclosed shaft into a chamber kept at a high temperature, and is then distributed through the air shafts we see in the walls. A suction fan draws the used air out at the roof, and a river of fresh air is thus constantly flowing through the theatre.

This picture is drawn from plans by James Keith & Blackman, engineers, and the system will completely change the air of the building 20 times an hour.

the sanatorium, failing to cure, at any rate prolongs life, the explanation is that the germs of septic infection cannot survive under the conditions of a sanatorium, all light and air, and no dust; and therefore the patient's lungs are not done to death by having those septic microbes added to the consumption microbes. The patient is saved, as doctors say, from secondary infection aggravating the original infection, and so his life is prolonged.

Undoubtedly it is the "open air" that does the good, saves the lives, or prolongs them; but our naïve idea that this depends upon some difference in the composition of the open air and indoor air is just as inaccurate as the idea that malaria was due to some poisonous quality in the night air derived from the "exhalations of swamps." Mosquitoes breed in swamps, and microbes breed in indoor dust. Infection is the key to the facts in both cases.

It will take a very long time for this perfectly simple and satisfactory explanation to be accepted by people at large, but its acceptance will lead to a great advance in the standard of health, by causing us to concentrate on the real danger.

The Wonderful Summer that Brought Tragedy to Vast Numbers of Babies

Wherever men have ceased to defame "night air," but have *killed mosquitoes*, in malarious countries or anywhere else, the disease has disappeared. The secret of success is to know what to go for. And, similarly, we shall abolish half, or rather four-fifths, of our disease in this country when we know what to go for.

The summer of the present year has furnished a tragic illustration. Vast numbers of babies died. Uninformed people—some of them, unfortunately, informers of the public—said that the state of the air, due to the prolonged heat and the absence of rain, caused the babies to sicken. It was nothing of the sort.

The trouble lay in the fact that there was no rain to wash away dust, and that dust and flies between them infected the babies' milk and other food with noxious and deadly germs. So long as we talk nonsense about the peculiar properties of the air, this will continue to happen, in greater or less degree, every summer, as it has done for ages past; but if we look for what is in the air, the dust and flies and microbes, and protect our children's food, all this ghastly and easily preventable slaughter will cease. For ages men talked about night air, and died of malaria; now they get rid of the night mosquitoes, and are well. If we thought less about the air in itself, and killed the day-fly as men kill the night-mosquito in the tropics, we should save our babies.

Surely enough has now been said to prove that we have hitherto looked rather unintelligently at these questions. But if we need further confirmation as to the real differences between different kinds of air, we can soon find it, in two ways.

The Mistake which was Made when Germany Invented the Open-Air Cure

In the first place, all the advance in our knowledge of disease for the last twenty years has gone consistently in the direction of disproving that any gases or constituents of the air cause disease, and of proving that diseases apparently due to the air, and diseases apparently conveyed by air, are due to microbes, and are conveyed by insects. To take the greatest instance, when the "open-air cure" for consumption was invented in Germany, the idea was that breathing the air of the pine-forests, in which the first sanatoria were built, would strengthen the patient and purify the body, his disease being supposed to be simply a kind of internal weakness and wasting. The open air was to invigorate, and the pine odour was to purify. The discovery of the microbe of consumption, and its conveyance by expectoration, and hence by dust, from the sick to the sound, means no less a revolution than the discovery of the mosquito's part in malaria.

This is not hair-splitting; it is practical politics for everybody. It means that if we only have the sense to control and prevent infection, which can be done *anywhere*, sanatoria in pine forests or anywhere else are unnecessary. It means that people may be cured, and their friends protected, anywhere, if they know what to fear and avoid.

Not the Air that Matters, but What is Put Into It

It means, moreover, that the cost of abolishing consumption, and all other diseases due to infection by and through the breathed air, may be reduced enormously if we once grasp the fact that it is not the air that matters anywhere, but what is put into it. Dust matters, dirt matters, animal excrement—in which flies breed and feed—matters, dark rooms, with darker corners, small windows, that let in little light, spitting, which infects the dust our clothes and boots and skirts gather and bring indoors, where its microbes are in safety, and we are therefore in danger—these are the things that matter.

In the second place, nothing is more unexpected or significant than the fact that, when we examine the different kinds of air, the differences are found to be absurdly small; and that when we try experiments in order to see what the effect of these differences upon our bodies may be, we commonly find no effects at all. The composition of the atmosphere of our planet necessarily varies in many ways at all times. But on the whole it remains astonishingly uniform. The wind, and what is called the "diffusion of gases," by which all the gases in a mixture tend to mix themselves equally throughout the mixture—these two agencies constantly tend to keep the composition of the air uniform. It is morally certain that, ninety-nine times out of a hundred, when people go away for "change of air" an ancient phrase invented for its obvious convenience when doctors knew nothing—they either get no change of air that any chemist can measure in any way, or such change as they do get is of no importance whatever.

What Really Happens When We Go for a "Change of Air"

In any case of so-called "change of air" it is certain that the air is the very thing in which there is the least change. There is change of scene, of room, of people, of associations, bodily and mental, change of food, and, above all, and more important than all else put together, change of thought, change of the mind's air, but so far as the air of the lungs is concerned there is no change worth mentioning, except, indeed, that, as a rule, when people take a "change of air," they do make the change that they spend far more of their time in the open air. Thus, the person liable to influenza and bronchitis, and colds and tonsilitis, and the consumptive also, persons who have been living largely in rooms richly infected with the germs in question—for which of us disinfects his house after having had a cold?—get away from these risks, real though invisible, in which they live, and profit accordingly. If we lived in a den with a wolf which was apt to bite, and then went away, we should not attribute our immunity from wolf-bite to "change of air," but to absence of wolf. Just so in the cases under discussion.

Within the last three years a number of new researches have added force to the general argument of this chapter. There remained several diseases, such as typhus fever, and the pellagra of the Italian peasant, and several more, which did seem to depend more probably upon some kind of injury wrought through the air than anything else. Probably smallpox and diphtheria should be added to the number of these diseases. Such insects as mosquitoes and gnats certainly had nothing whatever to do with the cause of them.

The Air that is the same Everywhere, and the Different Things it Carries

It was really the "confined air" of houses, or the "devitalised air," as unscientific people distinguish themselves by saying, that caused people to fall sick of these "low fevers," and their allies. Typhus fever, which used to be called gaol fever, was supposed to be due to the lack of ventilation in prisons. Let no one suppose that science does not now demand more and better ventilation than ever, as we shall see, but let us understand why we want it, and what else we want. Air has nothing to do with these illnesses, neither confined air, nor devitalised air, nor night air, nor slum air.

Here, again, let us always remember, it is microbes and insects that are man's greatest enemies. These low fevers, gaol fevers, starvation fevers, and the rest are microbic diseases of which the infection is conveyed by insects—after the parallel of malaria. The insects are things like blackbeetles and cockroaches, and other disagreeable and deadly creatures flourishing in dirt and darkness and in slums, which are the swamps of cities, where disease is bred for all classes, as "malaria" is bred in the swamps of the tropics.

The Air and Light that are the Enemies of Dirt Everywhere

The value of ventilation, of fresh air and light, in the modern prison, and in the model tenement and the garden village, is beyond all question, but we must know that this is not because there are magical differences between one kind of air and another, but because air and light are enemies of dirt, because they help to sterilise it, and because they help to reveal it, so that the housewife sees it and removes it.

The foregoing is probably quite unlike what the reader would have expected. But it is a very necessary attempt to clear the air of this discussion; and now we have cleared the air of its microbes and insects, we can see how to study it on its own merits. It has its own merits, and its own questions are important and interesting, but its inhabitants are vastly more so, and their existence had to be recognised before we could proceed farther.

THE CONQUEST OF THE STEAM TURBINE

A UNITED STATES CRUISER DRIVEN BY THE STEAM TURBINE

A FRENCH BATTLESHIP DRIVEN BY THE STEAM TURBINE

The English steam turbine, invented by Sir Charles Parsons, has made its way into the workshops and navies of all countries, and is rapidly displacing the older form of piston engine which held sway from the days of George Stephenson until recent years.

A REVOLUTION IN STEAM

The Greatest Step Forward in the Use of Steam Power since the Days of Watt and Stephenson

THE TURBINE THAT CAPTURED THE WORLD

It is a pleasant and surprising experience to leave the engine-room of any ordinary large steamer and go into the turbine-room of the swiftest of our vast modern liners.

In the first room, where piston engines are used, the brain is stunned by the thud, rock, and whir of the heavy, spacious, and intricate machinery—cylinders, pistons, and piston-rods, connecting-rods, cranks, and shaftings. In the second room, where the steam turbine is employed, all that can be seen of the engine is a large barrel of blue steel, from which emerges a quietly spinning shaft. There is scarcely any noise, and no vibration; less space is taken up by machinery, and instead of a group of grimy attendants, only a few men are required to look after several large turbines. The steam turbine is less costly to build than the piston engine, and cheaper to install, as it does not need heavy foundations. Less coal and very much less lubricating oil are used, and yet more power is obtained. In many piston engines about two pounds of coal are burned to obtain the energy which the steam turbine extracts from one and a half pounds of the same kind of fuel. In electric generating-stations especially the introduction of the turbine has reduced the coal-bill to two-thirds of what it used to be.

About fourteen years ago, when the steam turbine was still commonly regarded as an expensive toy, Lord Kelvin acclaimed it as the most important advance made in the use of steam power since the distant days when Watt invented his new prime mover. At the present time there can be no doubt that Lord Kelvin was right. By the invention of the steam turbine Sir Charles Algernon Parsons has effected a tremendous and far-reaching revolution in the use of steam power. He has greatly cheapened the cost of converting the energy of coal into electric power; he has given his country warships and passenger steamers speedier in movement and steadier in rough seas than the boats run with the old type of engine; he has enabled manufacturers who cannot yet afford to scrap their old-fashioned engines to get work out of the steam wasted by their present prime movers; and, what is perhaps his greatest achievement, he has taught our engineers the value of science.

The fact that the steam turbine is a British invention may seem very flattering to our national pride. It may appear quite natural that the nation which brought about the industrial revolution by inventing the old steam engine should have been first in the field in the discovery of the new principle of the steam turbine. But the plain truth is that Great Britain did not deserve the advantages which she is winning from the invention of Sir Charles Parsons. The steam turbine was conceived and worked out into a practical piece of machinery by a method opposed to the prevailing engineering practice of our nation. Sir Charles Parsons has not only provided his countrymen with a new prime mover of high efficiency, but he has given them a very necessary lesson in scientific research.

There are two ways of arriving at a new idea in mechanism—by rule of thumb and by science. In our country, things used to be slowly worked out by continual workshop practice; and our success has unfortunately made us rather sceptical of the larger and more scientific way of attacking a problem. Two hundred years ago, when little or nothing was known about the sciences of heat and movement, our engineers were building useful steam engines. It is said that a country boy discovered the superbly important principle of the automatic valve by attaching to the moving shaft the string he was employed to pull. By mother-wit of this sort, and good

craftsmanship, the old steam engine was gradually developed into a magnificent instrument of power.

It is true that many men of science pointed out that the most perfect steam engine wasted a very great deal of energy; our practical engineers were well content to waste it. From the point of view of mere theory they admitted that their engines were defective. In order to drive a shaft, the straight to-and-fro thrust of a piston had to be converted into a circular motion. This necessitated a web of machinery between the piston and the shaft, and considerable energy was thus lost in friction. Could not the steam be sent directly on to the shaft, as water was sent on to a water-wheel? No; it could not be done, said every practical engineer.

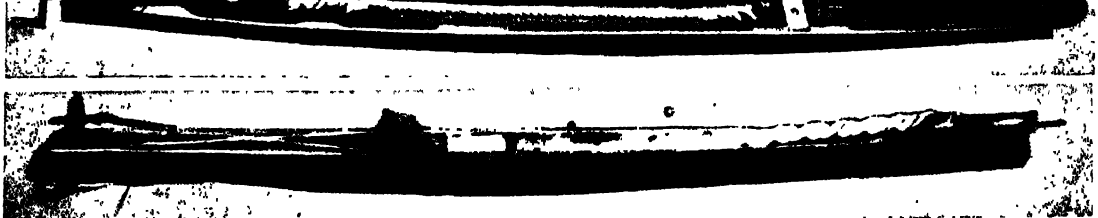
SIR CHARLES A. PARSONS
Inventor of the stea[m tu]rbine [Photo by Russe

But Sir Charles Parsons was, happily, something more than a practical engineer. A son of the famous Earl of Rosse, who built the largest telescope then in the world, Sir Charles was brought up in a circle where the study of science was pursued with disinterested passion. Among his tutors was Sir Robert Ball, the great astronomer. Mechanics, however, were the chief delight of Sir Charles and his brothers; and while still but lads they built a steam motor-car which ran at the rate of ten miles an hour. In 1873, at the age of nineteen, Sir Charles went up to Cambridge. He studied mathematics and came out eleventh wrangler. In 1876 he entered the Elswick Works as a pupil, and quickly distinguished himself as a promising young inventor. He tried to improve the steam engine by making the cylinder revolve; and he was fairly successful, so that a well-known firm constructed some engines on his new model. But in 1883 he came to the conclusion that the steam engine could only be improved by smashing it up and making it in an entirely new way.

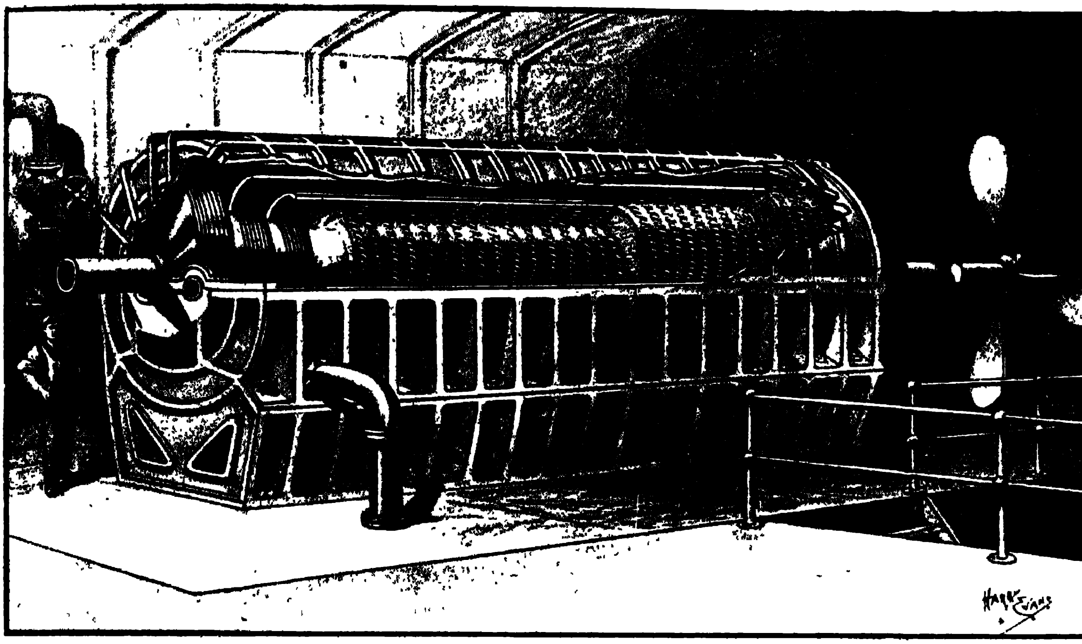
A great practical advance had recently taken place in electrical industry. The improvement in the water-wheel—as embodied in the water turbine—was enabling electrical engineers to utilise the power of rivers and water-falls. The water falling on the blades of the wheel produced a direct rotary movement. No rods, crossheads, or cranks were required. Could not steam be used on a turbine in a way similar to that in which water was employed? That was the question that Sir Charles Parsons asked himself.

Now, water acts on a water-wheel mainly by its velocity, and steam also has a velocity as it issues from the boiler. So the young inventor sought for information about the velocity of steam. He found, however, that nobody had troubled to make any researches into the matter. The engineers of the day were content with some knowledge of the pressure of steam on a piston—a pressure that could be felt to be almost irresistible. The little steam jet, issuing at immense velocity, was disregarded as feeble and wasteful.

The properties of this little steam jet were the thing that Sir Charles set out to examine by scientific experiment and calculation. He had in mind a steam-wheel, with a row of tiny blades sticking out around it, which might be set in motion by jets of steam. In 1884 the first steam turbine was built. It



THE LITTLE BOAT THAT BECAME A GREAT STEAMER
It was these tiny boats, worked by a twisted skein of elastic, which were really the forerunners of the turbine steamer, and it is out of experiments with these toys that the mighty turbine ocean liners of to-day have grown.



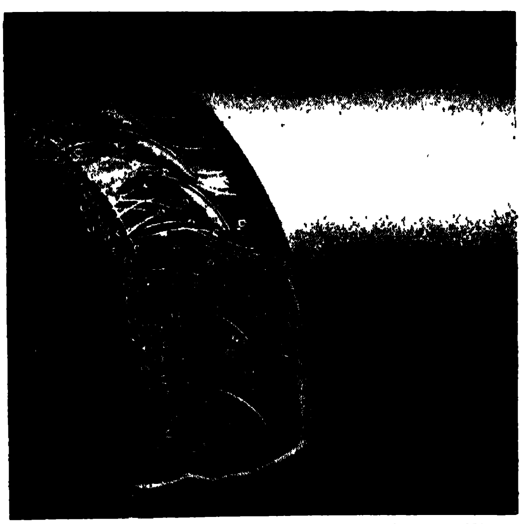
WHAT THE INSIDE OF A STEAM TURBINE IS LIKE

Inside a great fixed cylinder is a perfectly balanced shaft called a drum, with thousands of little vanes, or blades, arranged round it in the cylinde [illegible] the [illegible] the dr [illegible] olv [illegible] the [illegible] chin [illegible] The [illegible]onstantly directed upon the vanes of the drum by curved vanes fixed to the cylinder. At the far end the drum increases in [illegible] o the [illegible] long spaces outside the drum, and, pressing in the opposite direction, prevents the whole turbine from being pushed forward.

now stands in South Kensington Museum, beside the engine of James Watt and the Puffing Billy and the Rocket.

By this invention of a new prime mover, Sir Charles Parsons created a strange revolution in the history of the steam engine. For his achievement served indirectly to show that an ancient Greek was the real discoverer of the principle of the steam engine.

A hundred and thirty years before the Christian era, Hero of Alexandria described a machine which was worked by steam. But as he used steam power to obtain a reaction effect, he was regarded, until the appearance of the steam turbine, as a man who had begun entirely on a wrong track—on a track that had never led to anything useful. Hero's engine consisted of a hollow ball, mounted in the middle upon two pivots, one of which was hollow, and served as a steam-pipe from a cauldron below. The ball was fitted at top and bottom with two bent nozzles, through which the steam escaped. The unbalanced pressure due to the escape of the high-pressure steam, at an angle from the ball, caused the ball to revolve on its pivots. Unbalanced pressure of this sort is called reaction; an engine that works with this pressure is called a reaction engine.



HOW THE STEAM TURNS THE TURBINE

This shows how the particles of steam strike the vanes on the drum, and are then deflected by the vanes on the inside of the cylinder, so as to be thrown directly upon the next ring of vanes on the drum. The drawing is, of course, much simplified; the vanes are really long blades.

Now, the Parsons steam turbine is a reaction engine. So its utterly unexpected success carries back the fame of inventing the principle of the steam engine from Newcomen and Watt to the ancient Greeks. It was not, however, from the engine of Hero but from the modern water turbine that Sir Charles Parsons developed the principle of reaction.

There are two kinds of water turbines—reaction turbines and impulse turbines. The

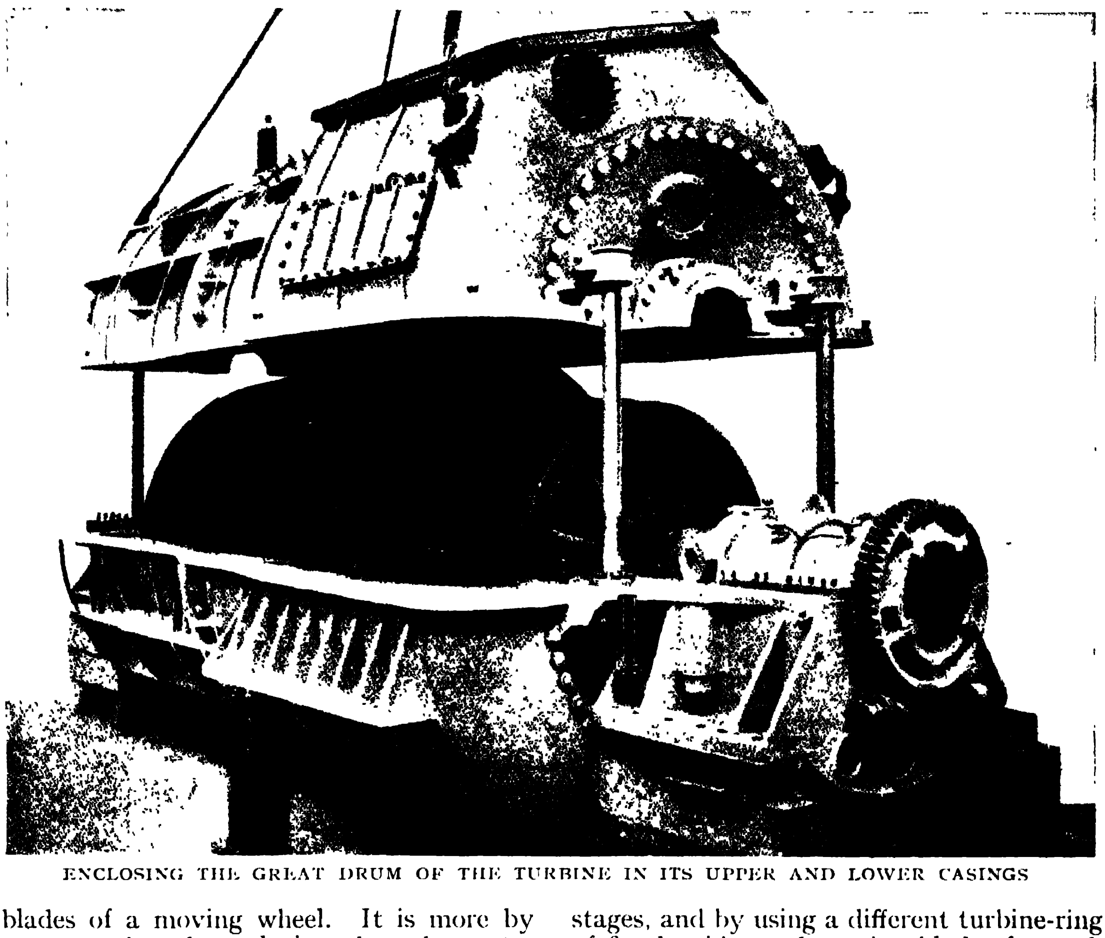
Pelton wheel is a good example of the impulse type of water turbine. It consists of a wheel with little buckets fixed on the rim. The water is discharged through a nozzle, and strikes the buckets in turn, and so makes the wheel revolve. In the water turbine of the reaction type, power is obtained from the falling water in another way. The water does not strike the buckets or blades on the wheel directly; it first passes a ring of immovable blades, which are called guides. The water passes through the guides, and these direct it on to the blades of a moving wheel. It is more by pressure than by velocity that the water acts on a reaction turbine.

The principle of the Parsons steam turbine is similar to that of a reaction water turbine. There are two wheels—one with immovable guides, which is fixed inside the great blue steel barrel; and another with moving blades, which is fixed on the large revolving shaft inside the casing. The steam enters through a hole in the bottom. It first passes through the ring of fixed guides, and these direct it, in a series of jets, on to the moving blades, with the result that the great shaft begins to spin rapidly round and round.

Now, steam—unlike water—expands when its pressure falls. Its velocity therefore is far greater. The moving blades—against which it strikes when it passes through the fixed guides—revolve at a high speed. The speed is indeed so great as to be useless for most purposes.

The inventor reduced the high surface speed of the blades by dividing the fall in the pressure of steam into a number of stages, and by using a different turbine-ring of fixed guides and moving blades for each stage. A Parsons turbine consists of a fairly large number of fixed wheels and of moving wheels. The fixed wheels are formed by inserting rings of immovable blades—or guides, as they are properly called—on the inner side of a cast-iron barrel; the moving wheels are constructed by inserting rings of moving blades on the large drum which turns round inside the barrel and ends in a projecting shaft revolving at a great speed.

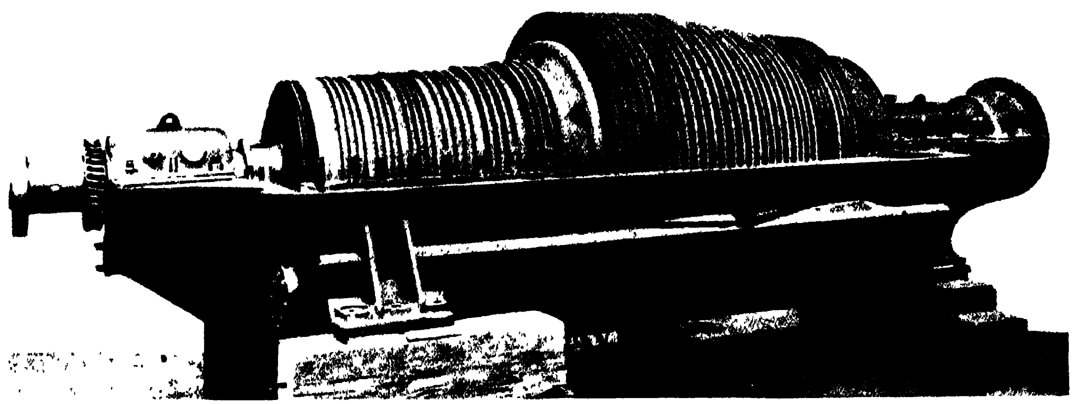
A steam turbine is thus formed of two



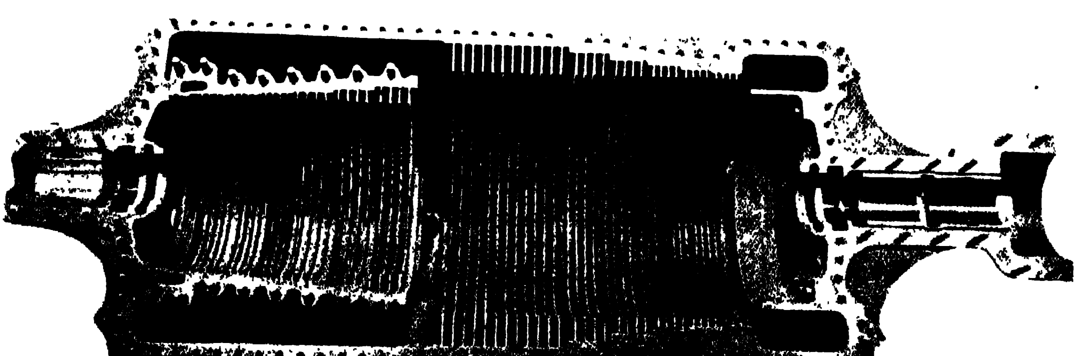
ENCLOSING THE GREAT DRUM OF THE TURBINE IN ITS UPPER AND LOWER CASINGS

THE DRUM THAT DRIVES A CITY AT SEA

ONE OF THE LUSITANIA'S TURBINE-DRUMS WITH ITS HUNDREDS OF THOUSANDS OF BLADES



THE DRUMS FIXED IN POSITION IN THE LOWER HALF OF THE CASING OR CYLINDER



LOOKING DOWN UPON THE LOWER HALF OF THE TURBINE CYLINDER, WITH ITS RINGS OF FIXED VANES
The turbines of a huge liner have more than a million blades, each one fixed by hand. The force of the steam is so great that one tiny vane, or blade, weighing only half an ounce, will exert a pull of three-quarters of a ton when the steam is playing upon it. The meaning of the word "turbine" is "whirlwind."

parts: the barrel—or cylinder; and the moving drum—or rotor. On the inside of the cylinder are many rows of inwardly projecting guide blades; on the outside of the rotor are many outwardly projecting rows of moving blades. When the rotor is fixed within the cylinder, there is formed a ring-like passage for the steam, and in this passage the steam first passes through the fixed guides of the cylinder, and is broken up into jets which hit against the moving blades. Then from the moving blades the steam jets pass into another row of fixed guides, and so on. It will be seen at first glance that the principle of the steam turbine is superior to the principle of the piston engine. In the piston engine, the steam enters a cylinder and presses forward a steel disc, mounted on a rod; the up-and-down movement of this rod has to be transformed into a revolving motion in order to turn the shaft. In the steam turbine the shaft itself is fitted with rings of little blades, against which the steam is impelled. This is, of course, a far more direct and efficient way of using steam.

LITTLE BLADES OF MIGHTY POWER

These rings of metal blades are [illegible]ally a development of the wooden wheel of the old water-mill, steam taking the place of [illegible] To keep up the supply of steam in a great liner like the Mauretania, there are twenty-five huge boilers with a heating surface equal to an area of three and three-quarter acres, and the boilers are heated by no fewer than one hundred and ninety-two furnaces, burning a thousand tons of coal a day.

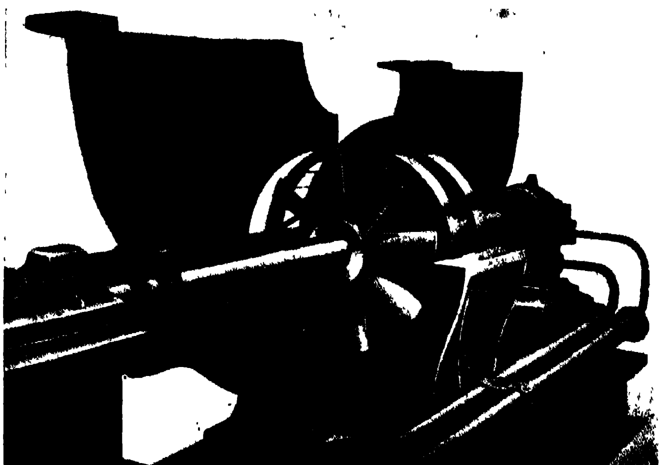
Unfortunately, there were several very great difficulties to be surmounted before the steam turbine was made into a practical prime mover. In the very earliest single-acting piston engine, steam was admitted during the whole stroke. This was a very wasteful way, and a much more economical method was quickly discovered by Watt. He cut off the steam as soon as it had pressed the piston one-fifth of the way down the cylinder, and thus let it expand and force the piston to complete its stroke.

Steam is really an invisible gas; the white cloud of vapour which arises from boiling water is not really steam, but minute particles of water formed by the condensation of the gas as it comes into contact with cold air. Like all gases, steam is highly elastic. Under pressure it becomes smaller in volume; and if the pressure falls without loss or gain of heat, the steam expands. In order to extract this energy from expanding steam, Sir Charles Parsons had to build his turbine in a way different from that in which a water turbine is constructed. He arranged his rings of fixed guides and moving blades in sets. The first set of rings was comparatively small; the second set was larger, and the third set was larger still. In the engines of the Mauretania there are more than a million blades, and the sizes of the blades are successively enlarged; those at the beginning, where the steam enters, are 2¾ inches in length, but those at the end are 22 inches long. As a matter of pure theory, each double ring of fixed guides and moving blades ought to be larger in size than the ring just before it, so as to make the most of each expansion of the steam. But, as a matter of practice, it is found best to arrange the rings in stages of the same size; in some of the Mauretania's engines, for example, there are five stages of rings. The end stage is long and high, and the three intermediate sets diminish in capacity down to the first small stage.

So successful was Sir Charles Parsons in making use of the expansive force of low-pressure steam that he is able to build turbines which run with steam at so low a pressure that it is emitted as waste from the best piston engines. Turbines, indeed, are now often attached to these engines in order to pick up the power they throw away. Some manufacturers make a still more remarkable use of the steam used in their industries: they divide its work between a high-pressure turbine with short blades and a low-pressure turbine with long blades. After the steam has driven the first turbine, some of it is led through a pipe and made to heat vats or other places where material has to be warmed; the rest passes into the low-pressure turbines, and produces in a dynamo electric power to light and drive the factory.

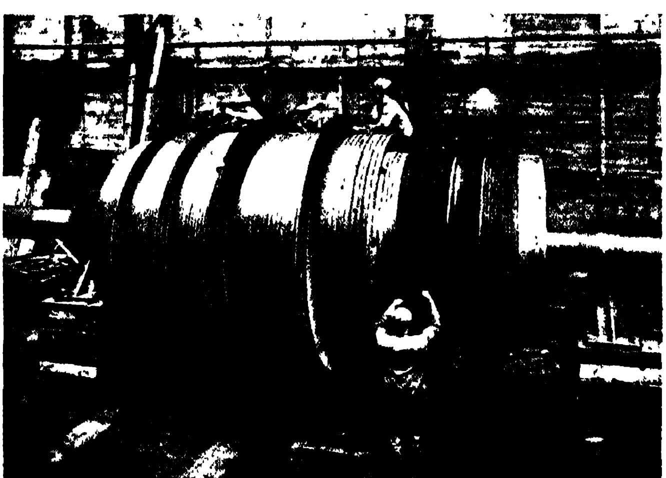
When Sir Charles invented his pioneer turbine in 1884, he hardly dared to dream that it would grow into a tremendous and wonderfully adaptable prime mover. All

he first aimed at producing was a new type of rotary engine for converting the energy in coal into electrical power. The little turbine that now stands in a glass case in the South Kensington Museum was born with two grave defects—it ran at a speed of 18,000 revolutions and more a minute—an excellent rate in a special kind of fan, perhaps, but useless for driving any machinery or for working any existing dynamo. But the worst point of all in the little experimental turbine was its extraordinary waste of energy. Engineers of the old school nicknamed it "the steam-eater," and hoped that its shocking inefficiency would convince its young inventor that his new-fangled principle was utterly impossible in practice. But the young inventor is hard to discourage, especially when he possesses, in addition to a large fund of new scientific knowledge won by long and costly experiments, a remarkable mechanical ingenuity. Finding that there was no dynamo that would run with his primitive turbine, Sir Charles Parsons invented one.



TURBINES FOR PULLING GAS FROM IRON
urbo-exhauster, shown in this p is revolutionising the manuf n and steel. It is a kind of fa which empties blast furnaces of gas

A dynamo is a device for transforming the power derived from steam or water, gas or oil, into electrical energy. Steam, for example, is used to drive a shaft into which there have been built, in a very complicated way, devices for generating electricity. In 1884 no piston engine could create, with its crank shaft, a sufficiently rapid circular motion for a dynamo. It was, indeed, this deficiency of the piston engine which had all along stimulated Sir Charles Parsons in his experiments with the new turbine principle. His pioneer turbine seemed at first, however, too much of a good thing, even for the purpose of generating electricity. Instead of spinning the dynamo round at 1,500 revolutions a minute, as the piston engine did with some loss of energy in gearing, the turbine sent it whirling at the terrific speed of 18,000 turns a minute. On every pound weight of the generating shaft there acted a centrifugal force of about five and a half tons, and as the shaft was composed of various materials that would not stand much strain, there was a danger of its splitting up and flying in murderous fragments about the room. Sir Charles, therefore, had to construct a new and stronger kind of dynamo before his turbine was able to work with safety. When this difficulty was overcome, the harder task remained of transforming the turbine itself from a steam-eater into a steam-saver. For four years the inventor went on with his costly and ingenious experiments, and in 1888 he produced a turbine which required only about a quarter of the amount of steam used in the pioneer engine.

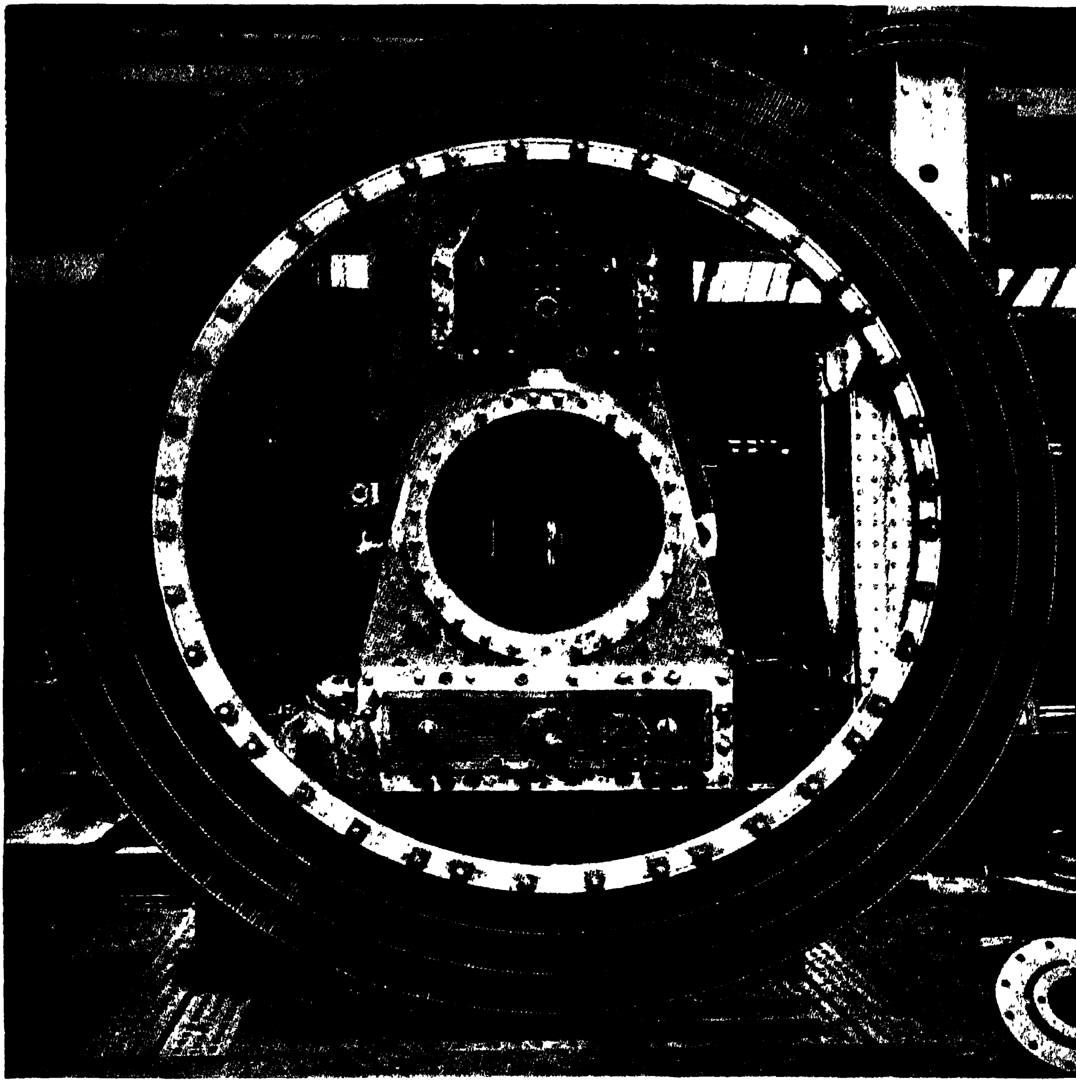


FIXING THOUSANDS OF BLADES ON THE DRUM OF A TURBINE
Made of copper mixed with zinc, the turbine blades are lightly hammered with wooden mallets into grooves inside the great drum, and then pieces of metal are fixed between them to hold them in place.

By this time the steam turbine had been elaborated into a splendid instrument of power, and Sir Charles Parsons was working

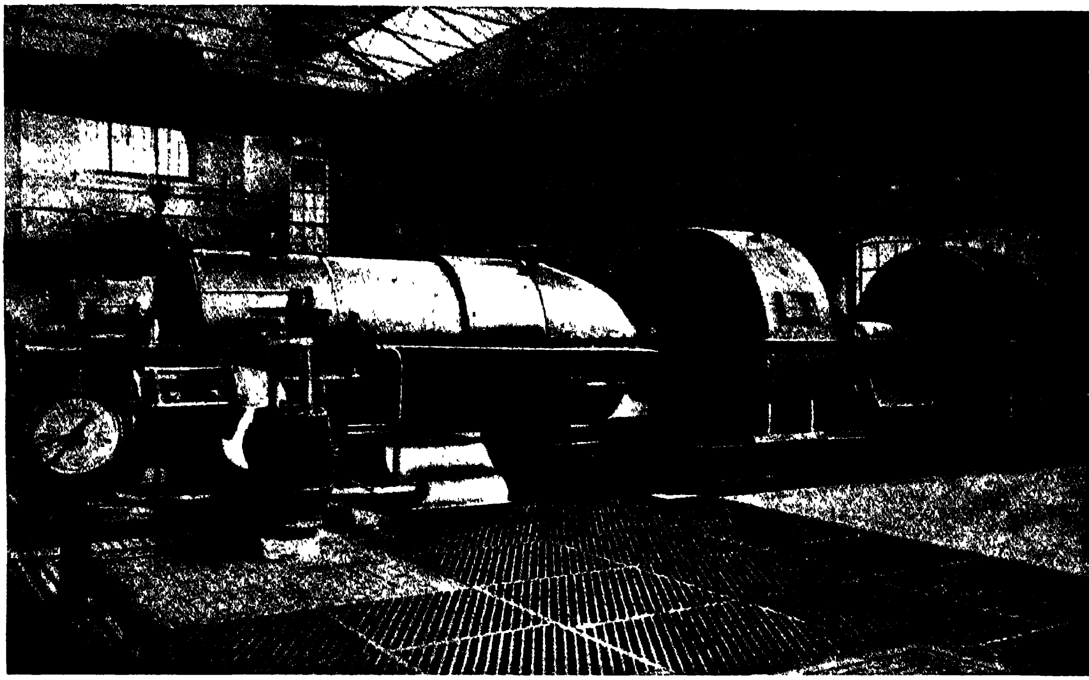
out the problem of adapting it to swift steamers. But in 1889 a difficulty arose. The firm of Messrs. Clarke, Chapman & Co., of Gateshead, with whom Sir Charles had been associated as junior partner, terminated his partnership, but retained all the rights in his wonderful patents. The inventor was naturally much upset at losing completely all the fruits of his genius at the critical moment of his career, but his spirit was not broken. Being prevented from using in any way his discovery and application of the reaction principle in steam turbines, he resolved to work out another design found in certain water-wheels. In 1890 he established the now world-famous works of C. A. Parsons and Company at Heaton, Newcastle, and built—a failure. His idea, however, was practical, and with some brilliant fellow-workers he continued his experiments for four years.

Now, in the very year in which the English inventor was compelled to abandon his reaction principle, a Swedish inventor, Dr. Gustave de Laval, of Stockholm, invented an impulse steam turbine. Generally speaking, the impulse turbine is set in motion in the same sort of way as a Pelton water-wheel, on the rim of which is fixed a ring of iron buckets, so that the water, falling swiftly into these buckets, bears them down by its impulse, and so turns round the wheel. De Laval placed a circle of metal buckets in the rim of the wheel, and



A RING OF THE MAURETANIA'S TURBINE-DRUM, WHICH WHIRLS ROUND AT 720 MILES AN HOUR
This shows how wonderfully the little blades are fixed upon the big drum of a turbine, ready to seize the mighty force of the steam that rushes upon them. In some turbines the steam rushes through at 48 miles a minute, a rate sufficient to go round the world in 8½ hours.

MAKING ELECTRICITY TO LIGHT A TOWN



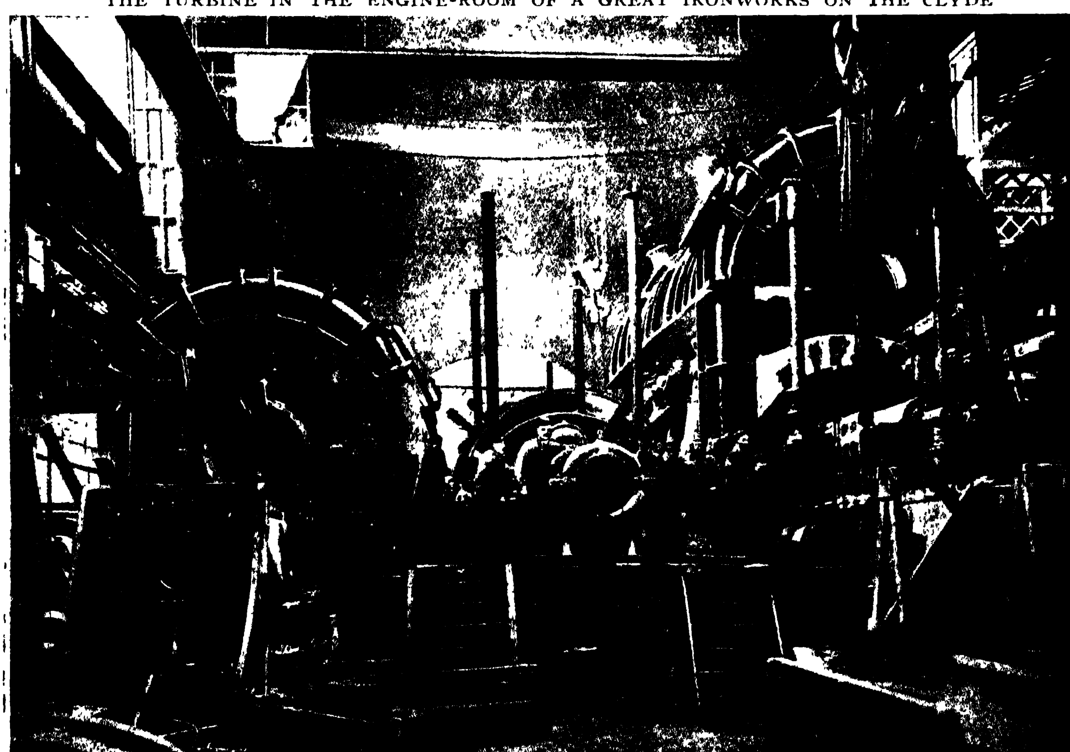
AN ENORMOUS TURBINE GENERATOR IN AN ELECTRIC POWER-HOUSE

TURBINES MANUFACTURING LIGHT AND POWER FOR A LARGE TOWN

Turbines are particularly valuable for use in electric power stations, as they generate the electricity at a much cheaper rate than any other kind of engine, and thus make it more and more available for industrial and domestic use. The lower picture shows the turbines of the Newcastle Electric Supply Co.

BUILDING UP TURBINES FOR A GREAT LINER

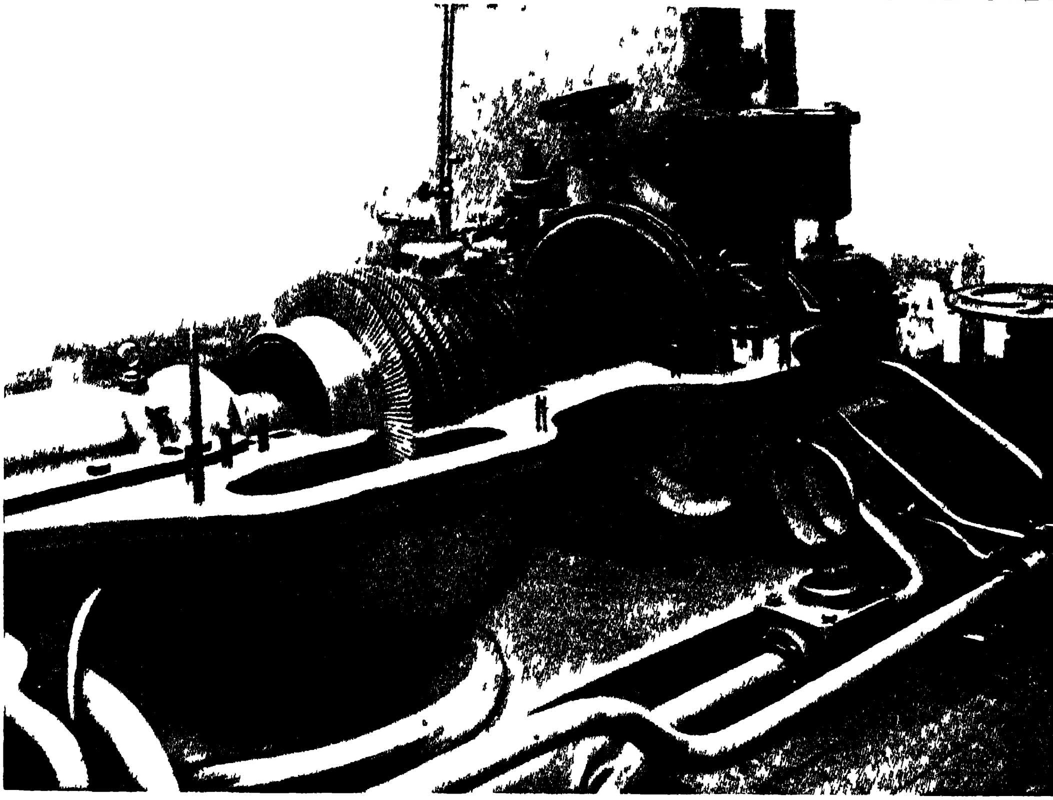
THE TURBINE IN THE ENGINE-ROOM OF A GREAT IRONWORKS ON THE CLYDE



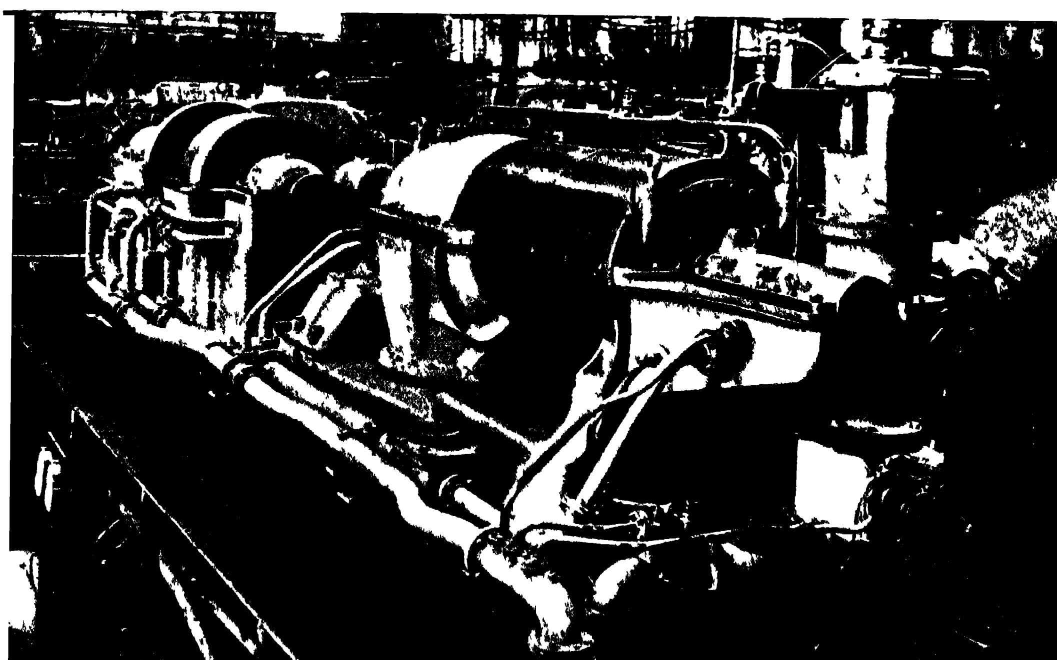
THE DRUMS AND CYLINDERS OF AN ATLANTIC LINER'S TURBINES IN COURSE OF CONSTRUCTION

The upper picture shows a set of powerful turbine-exhausters sucking the gases out of huge furnaces, in which iron is being melted. Turbines revolve so smoothly and quietly that even with the hand on the outer casing it is sometimes impossible to say if the turbine is working.

MIGHTY MACHINERY WORKED BY TURBINES



A NEW KIND OF PARSONS TURBINE FOR GENERATING ELECTRICITY

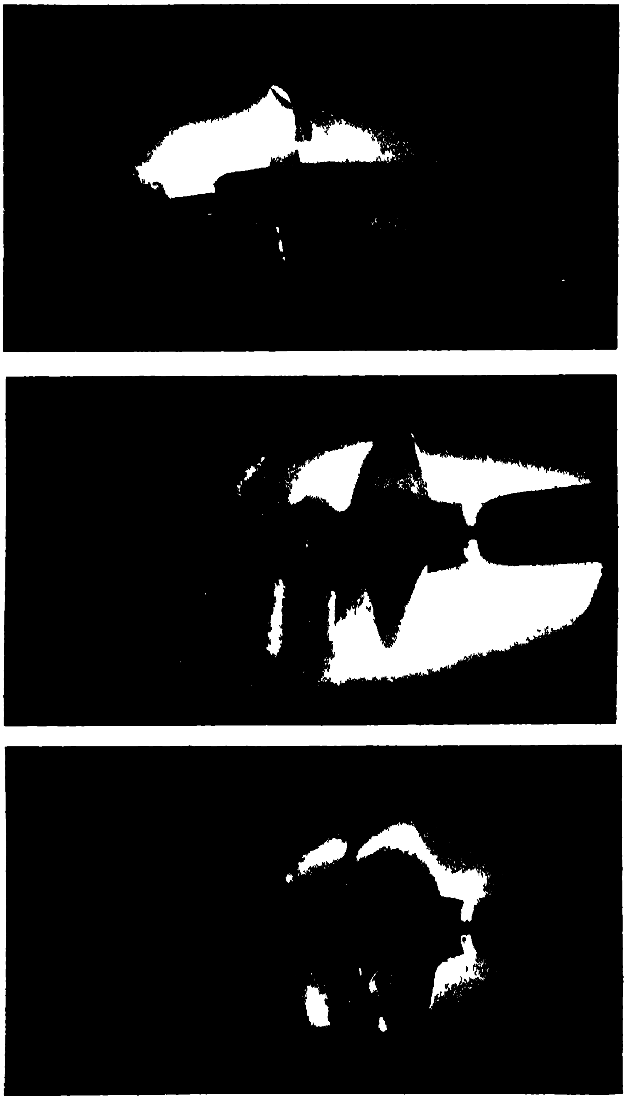


HUGE TURBINES THAT DRIVE A POWERFUL MILL FOR ROLLING OUT IRON AND STEEL PLATES

The turbine is fast becoming the industrial maid-of all work A high-pressure turbine will drive the heaviest machinery, and let out steam to warm the rooms A low-pressure turbine then takes back the steam and turns it into electrical power for lighting the factory or for whirling ventilating fans

directed into the buckets a jet of steam from a nozzle. By this simple arrangement he produced a steam turbine which was very effective in driving light machinery. It was, indeed, much more effective than the earlier Parsons reaction turbine, and for some time, especially on the Continent, its inventor was reckoned the pioneer of the steam turbine. Sir Charles Parsons was then unknown abroad, and ridiculed at home.

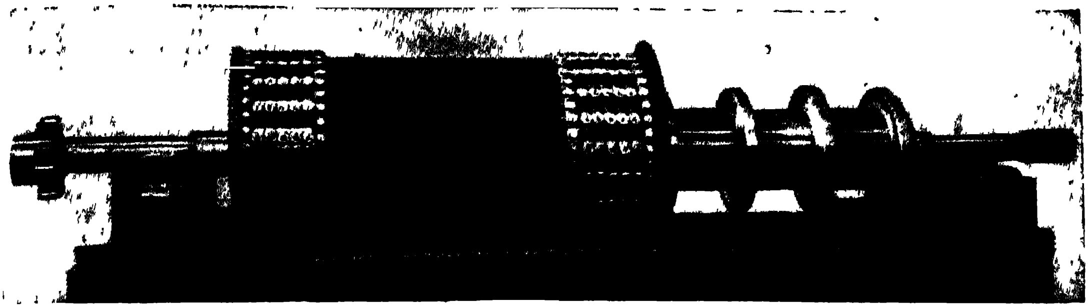
But at last, in 1894, Sir Charles came into his own, as he was then able to recover his patent rights in his original invention. He at once dropped his experiments on the new type of turbine. His five years of laborious and purse-emptying research had convinced him that the old turbine of 1884 was the best of all steam prime movers. A group of fine engineers of the scientific school, now wild with enthusiasm, helped him to overhaul the poor old "steam-eater." First a long series of tests was made to ascertain the best form for the blades; then the interesting problem of clearances was solved. When the casing, in which the fixed guides are set, is screwed down on to the drum—into which the moving blades are inserted—space must be left so that the guides do not touch the drum, and so that the blades do not scrape the inside of the casing. This space is called a clearance, and there are really two clearances—the casing clearance, and the drum clearance. If they are appreciable the steam will escape along them instead of doing its proper work between the guides and blades. These clearances, however, were now reduced to microscopic proportions, and the steam, as it passed out of the turbine, was sucked into a condenser. By such means the steam-eater was transformed into a marvel of economy and power. It was ready to sail the seven seas and spread over the world on its marvellous career of conquest.



WHY THE FIRST TURBINE WOULD NOT GO

The first turbine boat on her trials did not go at the speed expected, and this was found to be because the propeller whirled at such a rate as to create an air space round it, so that the screw revolved in air and did not touch the water. The difficulty was overcome by altering the shape of the screw. These photographs show the air cavity round the screw.

The first marine turbine, however, was a curious failure. Tried in 1894, on a little boat named the Turbinia, it sent the propeller whirling through the water at a far higher speed than the best piston engine had done, but the boat itself, instead of going quicker than an ordinary vessel, only crawled through the water! More experiments had, therefore, to be undertaken. A copper tank was filled with water, and windows were placed on both sides. In the water a propeller was revolved by means of a shaft entering the copper tank. Photographs were taken through the windows. It was then discovered that when the propeller spun at 1500 revolutions a minute a kind of cavity was created, and the energy of the screw was expended in maintaining this air-space, instead of pushing the water away, and sending the ship forward.

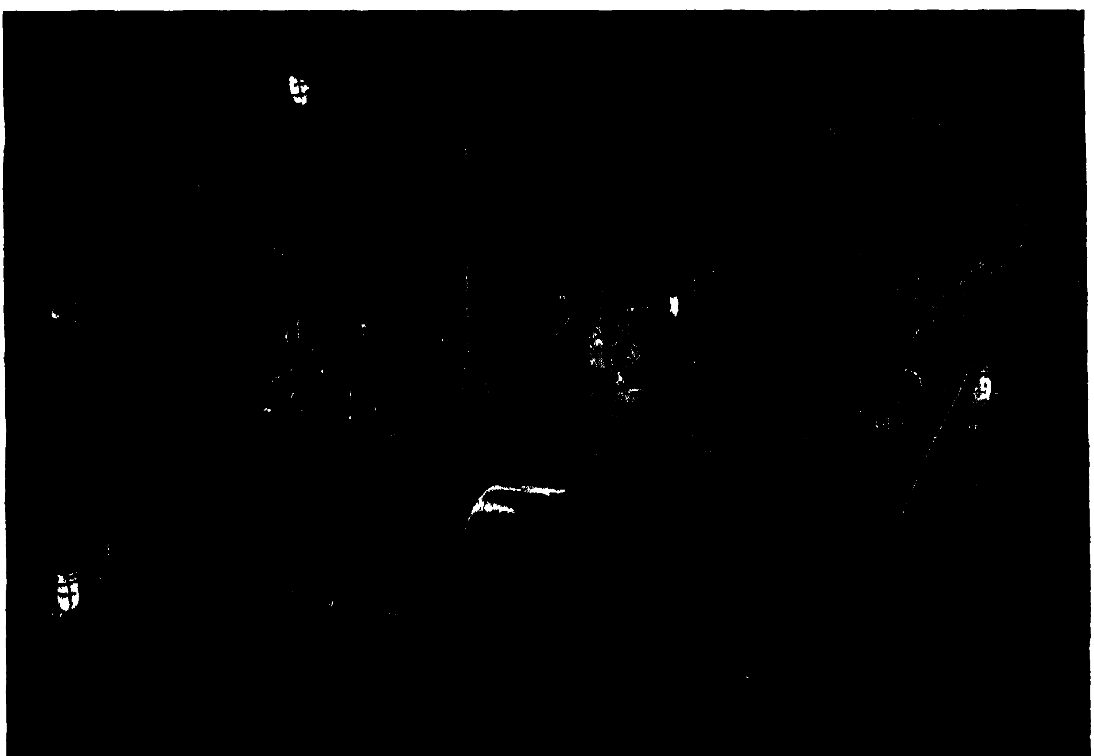


HOW THE TURBINE TURNS COAL INTO ELECTRICITY

This is a photograph of the end part of a turbine shaft used in making electricity. Into it are built coils of wire and electrical conductors, and as it spins it generates a very powerful electric current.

Having arrived at a clear understanding of the strange new problem of "cavitation"—as the formation of these air-cavities is called—Sir Charles Parsons invented a new form of propeller, and a new arrangement of the screws. In 1897, at the great Naval Review, the tiny "Turbinia" astonished the world by its wonderful speed of thirty-four and a half knots per hour, and the British Admiralty gave the Parsons Marine Steam Turbine Company an order for a turbine-driven destroyer. The Admiralty demanded that the vessel should have a speed of 30 knots—the highest then obtainable with piston engines. With the turbine and the new propellers, however, the destroyer ran at the rate of 37·113 knots, or at about 43 miles an hour. The steam turbine had arrived!

It has now shortened the distance between England and America; it has cheapened the production of electrical power; it has introduced new economies into the manufacture of iron and steel; and a series of experiments conducted during the last two years has shown that it can be used to drive slow cargo boats more cheaply than can be done with any kind of piston engine. In almost every country the Parsons turbine is ousting the old type of engine, and Great Britain has regained her ancient place in engineering science.



THE NEW KIND OF ENGINE-ROOM ON AN OCEAN LINER, IN WHICH THE NOISE AND WHIRL OF THE OLD ENGINES ARE ABSENT

A PICKING DAY IN THE COTTON FIELDS

Cotton is the most valuable of all the vegetable fibres of the world, and the growing, spinning, and weaving of cotton probably employs more workers than any other industry The United States, with its 28 million acres of plantations, supplies three quarters of the world's cotton The fibre has to be picked by hand and from a single pound of it may be spun a thread reaching from London to Sheffield.

THE COTTON OF THE WORLD

The Story of the Flower of the Field that Gives Work to Millions and Clothes Mankind

THE SOURCE OF LANCASHIRE'S PROSPERITY

An interesting argument might be started as to which vegetable growth is most important to man. Is it wheat for the feeding of the man of the earth's temperate regions? Is it rice, for the sustenance of the people of the warmer climates? Is it the potato, which enables men to grow more food per acre than in any other way? Is it cotton, which clothes the vast majority of mankind, in part or wholly, and also indirectly provides valuable food? Is it the vine? Will it be the rubber tree?

While most of the people who read and write books would decide for wheat as the most important vegetable product, a case might be suggested for cotton, because admittedly its enormous importance is enhanced by the fact that the earth does not provide any substitute for it. It is cotton or nothing for clothing the poor people of hot lands.

Whether cotton is or is not the most important vegetable product, it certainly is the chief vegetable fibre. Nothing similar is grown to such a stupendous extent, or occasions the expenditure of such varied manipulative skill. In its manufactured form it is known to every man between the arctic circle and the remotest Equatorial swamps. Its growth has caused the greatest transplantation of a backward race from continent to continent whereof the world holds record. African manhood has been permanently dumped into, and has annexed, certain of the American States at the call of cotton. It rules also the destinies of the most populous county of England.

Gradually, too, its predominance is extending, for decade by decade it clothes an increasing percentage of mankind while its competitors in the world's clothing trade are falling farther behind in the race, even when they are not slackening their pace. At present, cotton has no rival; nor will it have until a form of patent clothing is invented equally comfortable and attractive and more economical. Mankind wears three times as much cotton as wool.

There is a striking universality in the use of cotton throughout the world, if not through time. Though wool was the wear in ancient Europe, and linen in ancient Egypt, the use of cotton was known, as an echo from the East. Herodotus was aware of the "fleeces from the trees," and admired their effect in fabric form. For nearly three thousand years, India has had cotton manufactures unsurpassed in certain qualities. The word "calico" itself is from the Indian town of Calicut. When the Spaniards appeared in America they found the natives of the Southern continent wearing cotton garments so well dyed that they sent them home as curiosities and as proofs of the stage of civilisation attained. The countries that now supply the world with its calico prints were backward in beginning the manufacture of cotton cloth.

The modern change has been brought about, of course, by the impetus of invention and an early start with machinery. Europe first received the industry from the Moors, and it is said to have come to England from the Turks by way of Flanders, but there was no considerable progress until Richard Arkwright invented his "water-frame" for spinning, which enabled an all-cotton fabric to be produced by machinery, cotton being used for both warp and weft. Then England began to make the world's cotton goods, and the American States to grow the cotton.

Cotton can be grown only where there is sufficient, but not too much, moisture, with plenty of sunshine. It is subject to many diseases, and, except under constant conditions of a favourable character, has a somewhat precarious life on the level of

prosperity. It has a long growing season from first to last. Fresh seed is planted in March or April by machinery, on prepared and manured ground, from which last year's stems have been cleared, the rows being from three and a half to four feet apart, and the seed-holes not less than twelve inches distant from each other in the rows—four or five seeds in each hole.

The Beautiful Ball of Tuft that Springs out of the Bursting Cotton Pod

In May, after the plants have been thinned out, showers are needed, and the active period of growth is from early June to the middle of August. The plant rises as a shrub from two to four feet high, branching broadly at the bottom and much less broadly at the top. The flowers appear in June, and are very short-lived. On the third or fourth day they fall to the ground, after having turned from white or yellow to a darker and redder colour, and they leave at the calyx a small capsule, which grows to the shape and size of a hen's egg, ripening, through dry weather, in August, and bursting open in September. The bursting pod, or boll, discloses a beautiful tuft of white lint, springing in separate hairs from the coating of a number of seeds.

The object of these gossamer protuberances is ultimately to float the seed through the air to its next year's growing ground. That, of course, is not allowed : the seed and the attached lint are picked from the pods in time to prevent it. As the maturing does not all take place at the same time on the same plant, the gathering goes on for many weeks—through September and October into November. The picking, a most tedious process, is done by hand, effective machine-picking being one of the great needs of cotton culture that are still unmet.

The Ball of Tuft that will make a Thread to Reach from London to Sheffield

The cotton plant is found in a wide tract of the world, its characteristics varying with kind, soil, climate, and treatment. It has long held its own in India, thrives well in Africa, and was indigenous to the West Indies and South America, but not to the United States, though the States now furnish 65 per cent. of the supply of the whole world. It is really a perennial shrub, but is treated as an annual and is planted afresh each year.

Five different types of cotton may be distinguished from the rest—sea-island cotton, the longest and best quality, grown on the coasts of the Southern American States ; long staple upland cotton, an Asiatic type carried to America ; short staple upland cotton, of American origin, but carried to other countries—the most general form of the American product ; tree cotton, an Indian perennial of low value ; and bush cotton, an Indian variety used for muslins. Let us trace the average cultivation of the average plant on an "upland" American farm.

It is almost incredible to the traveller on one of these farms, as he gazes at the balls of tuft on the cotton plant, that a single pound of the finished fibre from these balls can be spun out so that the thread will reach 160 miles—from London to Sheffield. Let us consider how this feat is achieved.

The cotton, when picked from the pod, consists two-thirds of seed and one-third of fibrous filaments, or lint. The usual cost of picking is two shillings for a hundred pounds weight of seed cotton, and a fast picker can gather 300 lb. in a day. A good average cotton crop will be about twice as remunerative as an average wheat crop at American prices, and is only half as exhaustive of the soil. A medium yield is about 190 lb. of lint to the acre, irrespective of the seed, which is worth about one-fifth of the value of the crop of lint. The picking of the cotton is always carried on in the sun ; and after it is picked and loosely baled, or put in bundles, it is left in the sun to dry.

The Invention that Appeared the Moment it was Wanted

In the early days of cotton-growing, the separation of the seed and lint was the most tedious work associated with the plant, and kept down production. The rise of the American trade into prominence dates from the invention of what was called the saw-gin by Eli Whitney, a Massachusetts man, who, after being educated at Yale, found himself a schoolmaster without employment in South Carolina, and, seeing the need for a better gin, invented one. Since that time the American cotton produce has enormously increased, multiplying itself four thousand times.

In the case of sea-island cotton, the seeds are but lightly entangled in the long and silky cotton fibres, and can be more easily removed, but in the upland cotton, which is the common crop, they are tenaciously attached. The second half of the eighteenth century had witnessed great advances in spinning in England. John Kay of Bury, Lewis Paul of Birmingham, James Hargreaves of Blackburn, Richard Arkwright of Preston, and Samuel Crompton of Bolton, had successively introduced improvements,

PACKING THE COTTON FOR THE SHIPS

The cotton, as it is gathered, is taken to a ginnery, where a machine like this separates the fibre from the seeds. The seeds, when pressed, give out a valuable oil, in which a great trade has been built up.

The cotton fibre is packed into great bales by a hydraulic press, and is then fastened by iron bands ready for shipment to the cotton mills of the world. A bale weighs usually four hundred and fifty pounds.

culminating in Crompton's "mule," which would run 360 spindles at once.

But where was the cotton to come from to keep this new machinery at work? Obviously, it could not be supplied if the seeds were to be picked from the cotton by hand. Just at this moment came Eli Whitney's saw-gin for tearing the lint from the seeds with such expedition that his machine and one man could do as much work in a day as two hundred men engaged in hand-picking—a rate of speed now enormously increased. It is true that the gin damaged—and, indeed, continues to damage—much cotton, cutting and breaking the fibres by its rough methods, but it gets through the work, and gives the multitudinous spindles of Lancashire and the Western world an ever-increasing supply of raw material.

In the earliest days of the saw-gin it was erected, if possible, over a stream, in order that the seeds, as they were separated from the fibre, might be dropped into the current and swept away. All that is now changed; and it is calculated that the commercial value of the seed, once treated as refuse, is eighteen millions sterling per year for the American States alone. If the cotton plant made no lint for the clothing of man, it would be worth cultivating for the value of its seeds.

RAW COTTON AT THE SPINNING MILL

Twenty-five thousand million miles of yarn are spun in England from fibre like this every year—a length 270 times as great as the distance from the earth to the sun. The United States alone grows each year 6500 million pounds of this fibre, more than enough to clothe every human being on earth in a cotton suit.

The seed is sent to the oil-mills, and there is treated so as to produce cotton-seed oil, feeding cake for cattle, and fertilisers for return to the soil. At the oil-mills the seeds are first screened and cleaned, and then the remainder of the short lint still adhering to them is removed—less than 30 pounds being recoverable at this stage from 2000 pounds of seed. The seeds are then hulled—that is, sliced up by machinery—so that the outer coverings are separated from the kernels, or "meats." The "hulls," which are the lighter part, are screened away, and amount to about 850 pounds in 2000 pounds of seed. They are used to make bran as a cattle food, and so serve indirectly as a manure, while the fibre makes a high-grade paper. The kernels, which amount to about half the original weight, are crushed, then cooked, then placed under a hydraulic press, so that the oil is squeezed out. The solids remaining are next either ground into meal for a cattle feed, or pressed into cotton-seed cake for the same purpose. The crude oil amounts to about forty gallons from a ton of seed. The settlings of the oil are used in soap-making, and the clearer oil is refined by heating, and by treatment with potash, which causes its impurities to be deposited. This refined oil is known in commerce as "summer yellow," or, in its purest forms, as butter-oil, and it is used in the manufacture of oleomargarine and butterine. Under cold pressure it is changed into salad-oil, and becomes an alternative to olive-oil, or perhaps is sold as pure olive-oil.

When bleached it finds a market as a substitute for lard, or is known as cottoline. Under cold pressure it becomes "winter white oil," and is used in the manufacture of medicines, as well as for miners' lamp-oil and for soap-making. The United States alone produces 70,000,000 gallons of cotton oil per year, selling for £3,000,000. The most familiar form in which cotton-oil meets the eye of the householders is in the anchovy and sardine tin, the fisheries of Western France being almost entirely supplied with oil from the cotton-fields of the United States and Egypt.

THE FIRST PROCESS AT THE MILLS

As soon as a bale is unpacked, the tightly pressed cotton is passed through a machine such as is shown here, called a bale breaker, where spiked or fluted rollers pull the fibres into a mass of loose fluff.

Here we see the spiked roller tearing the mass of fibre apart, making it loose enough for succeeding operations. The fibre is carried away to another room automatically on a travelling lattice.

The price that raw cotton will command depends on the ripeness, length, and fineness of the fibres. Unripe fibre has to be removed ultimately. The farmer, when paying the ginner for his work, may wisely pay for the running of the machinery at a lower speed so as to preserve the quality of his produce and secure the exclusion of waste matter. After ginning, the cotton is forced into as small a bulk as possible under a baling-press, because freightage is payable on bulk as well as weight. An average American bale weighs 450 lb., Indian 400 lb., Egyptian 700 lb.

The Strange Concentration of Cotton in the American Cotton Fields

The question of the concentration of the growth of cotton in one place—the Southern States of the American Union—has engaged the attention of the manufacturers of cotton goods in all countries since the calamitous ruin of the business by the stoppage of supplies of cotton during the American War close on fifty years ago; but though there has been a considerable development in India, and a notable increase of production of good qualities in Egypt, the States still supply the world with 65 per cent. of its cotton crop. Among the cotton-producing countries are Brazil, the West Indies, Peru, China, Corea, Japan, Turkestan, West Africa, and the East Indies. The manufacturing nations stand thus in the order of their cotton exports: (1) Great Britain, (2) the United States, (3) Germany, (4) India, (5) France. But the United States and India also import cotton goods largely, more largely than they export them, and Great Britain easily leads the world in this manufacture. Only about 25 per cent. of the Lancashire-made cotton cloth is used in Great Britain.

Why Lancashire is the Great Cotton-Spinning Centre of the World

Why is it that Lancashire has gained, and so long held, the foremost place in the spinning and weaving of cotton? A great deal has been due to the energy of its people, and the perfection to which its business has been organised, and the natural divisions of labour adhered to; but there can be no doubt that the peculiar fitness of the climate for the work is one of the secrets of the unexampled success that Lancashire has attained. A certain amount of humidity is essential for cotton-spinning, so that the fibres may cling, while dampness is a disadvantage. If the climate of a cotton-spinning country has not this humidity it has to be produced artificially. In Lancashire the requisite conditions are naturally present, and so the county has been able to retain the pre-eminence that was reached at an early period by invention and has since been sustained by organisation.

The manufacture of cotton is divided into two well-marked series of processes—spinning and weaving. We must now trace the cotton, after its arrival in the form of compressed bales at the English mill, through the series of processes of extraordinary complexity known as spinning. The first operations are the breaking of the bales and mixing of the cottons they contain. As the bales include various qualities of cotton, it is necessary that they should be well mixed so as to secure blending and uniformity, otherwise the manufactured material would not be reliable throughout. The best and worst cottons are not blended, but only those which fairly approximate to each other. The mixing is done generally by a machine known as the Cotton Puller.

How the Cotton is Cleaned and Carried Away on a Current of Air

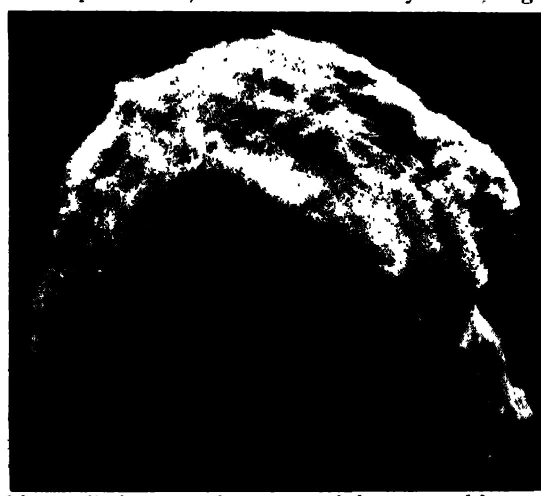
The cotton is then "opened" out so as to be cleansed of any seed, leaf, or dirt that it may have retained. It is fed through a machine to a beater, which frees it of its impurities, and the cleaned cotton is borne away on an air-current produced by a powerful fan, and plastered on a sieve cylinder through which the air passes. Having gone through this cleansing process more than once, the cotton is passed between compression-rollers and formed into a roll, or lap. This opening and cleaning process is sometimes repeated, it may be more than once, through a "scutcher"—another beating machine—and a thicker lap of more perfectly cleansed cotton is formed into a large sheet.

Carding now begins. The purposes for which the cotton is passed through the carding-engine are—to complete the process of cleaning, to disentangle the fibres from knots so that they may become parallel, to extract the broken fibres, and to deliver the cleansed cotton as a loose rope, or "sliver," ready for it to go to the "drawing-frame."

The drawing-frame is a machine for improving the "sliver" by making its fibres parallel and its thickness and strength uniform. Six slivers are put into the machine, and are drawn into one, and this is repeated, usually three times, till a rope of untwisted cotton has been formed

CLEANING THE COTTON FOR SPINNING

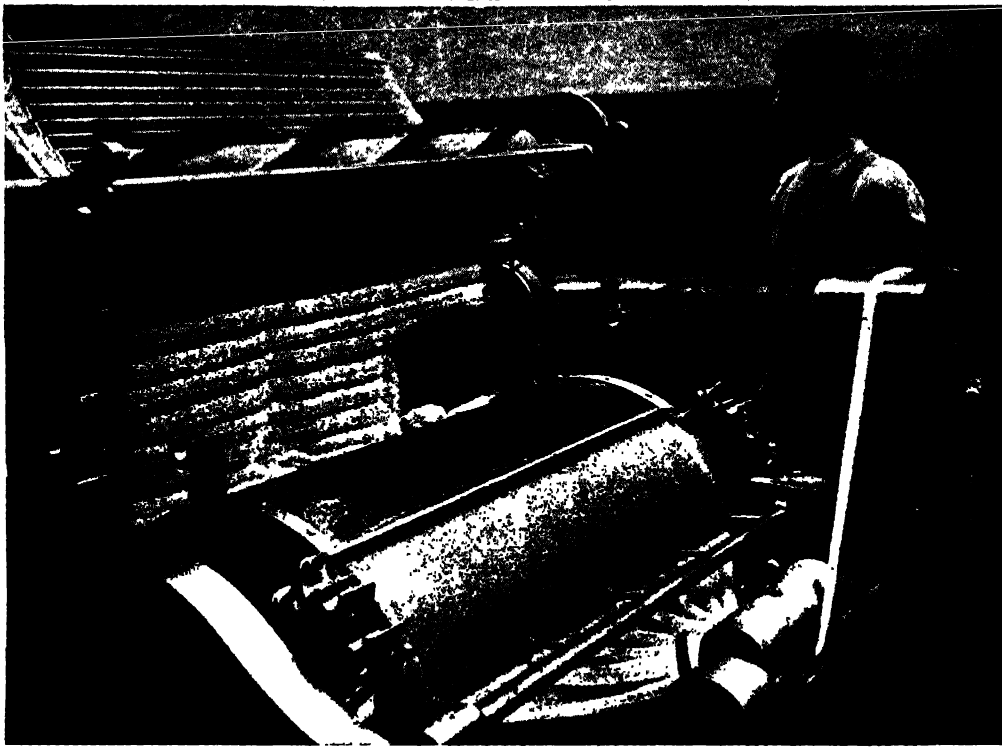
The cotton fibre is passed through a machine known as an opener, which further loosens it, clears it of impurities, and rolls it into a sheet. The cylinders are perforated, so that the dirt may fall through.



The work of cleaning is continued by another machine called a scutcher, named from an old word meaning to beat or roll out. These two pictures show cotton fibre before and after the scutching process.

Here is the scutcher at work. It is something like an opener, and not only cleans but continues the rolling out of the cotton fibre until it is in a sheet of a uniform thickness ready for the next machine.

A COMB WITH MILLIONS OF TEETH



The fibre is passed through this carding-machine and made into a rope, called a sliver. The machine really combs the fibres by means of tiny teeth, of which one machine may have seven millions.

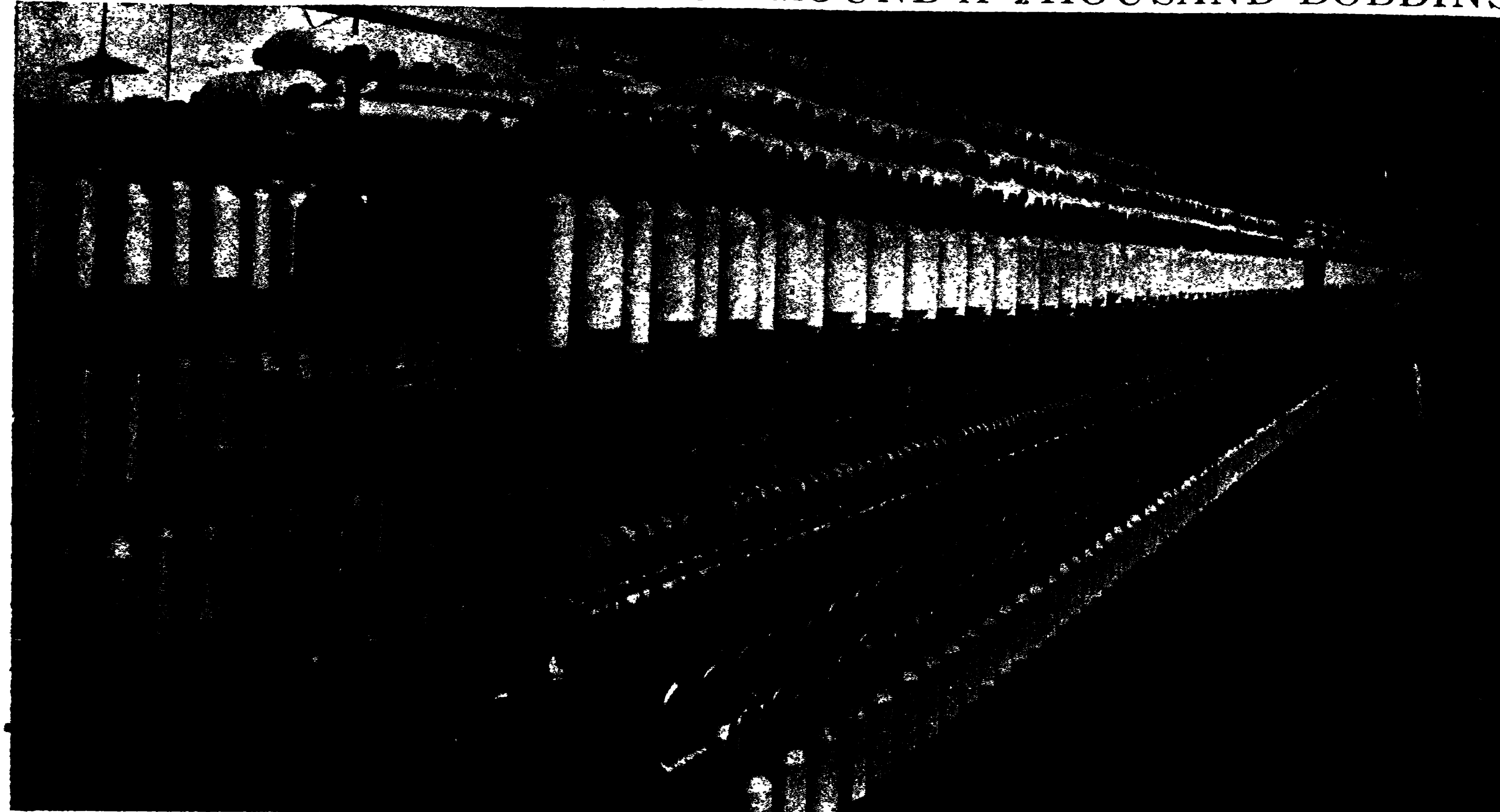
A number of slivers are run together in a combing-machine, shown here, which further insures the parallel arrangement of the fibres and mixes them so that all are of uniform length.

GIRLS WIND THE COTTON ON THE BOBBINS

The united slivers are now passed through the drawing-machine, which draws out the band to the width of a single sliver. The strands are thus made uniform in thickness and the fibres more parallel.

The next process is known as slubbing. The cotton is brought in cans from the drawing-machine, and passed through rollers which draw the strands out further, twist them slightly, and wind them on bobbins.

A MILLION YARDS OF COTTON ROUND A THOUSAND BOBBINS



One of the most wonderful sights in the world is the scene in this photograph. In this machine, called a roving-frame, millions of yards of cotton fibre are constantly rushing between rollers and being wound upon thousands of bobbins. This is the last process before the actual spinning begins.

The resources of the greatest cotton mills in the world, the vast works of Horrockses, Crewdson, & Co., at Preston, were placed at the disposal of POPULAR SCIENCE for this series of photographs, most of which represent the magnificently equipped mills of this firm, from which cotton goes out to all parts of the world.

A MARVELLOUS MACHINE DOING THE WORK OF 4000 WOMEN

No more wonderful machine has ever been invented by man than the spinning-mule. It almost seems to have brains as it works, and, tended by only a man and two boys, it can spin as much cotton as four thousand women could do in the olden days. A single machine such as the one shown in the picture has as many as thirteen hundred spindles, capable of spinning and winding four thousand miles of thread in one day.

of even strength. It is now ready for what is called "slubbing"—that is, taking a passage through machinery which attenuates the thread and gives it a strengthening twist, a process repeated and extended in the "intermediate" and "roving" frames. Some of the most delicate mechanical improvements in spinning machinery have been concerned with the attenuation and twisting of the strands of cotton and the winding of them on bobbins, for the "rovings," as they are called, remain very weak at this stage.

The Many Purposes for which the Cotton Thread may be Used

The rovings are now ready to be spun into thread. This is accomplished either on a spinning-mule—an invention by Samuel Crompton in 1779, which remains in principle as he left it, but has been improved in detail by innumerable successors—or on a ring frame, which is an improvement on Arkwright's machine. First the rovings are drawn out to a greater attenuation in the mule—say, to nine times their former length—and are given twists according to the fineness of the yarn—say, twenty-four per inch. The ring-frame is of comparatively simple formation, spins continuously, and is entrusted to women and girls for the production of the less fine yarns, while the mule has extremely complicated mechanism, with intermittent working time, owing to a reversing action, and its manipulation needs skilled workers.

The thread is now ready for use if it is to be worked into the weft in weaving; that is, into the set of threads which in a piece of cloth run from side to side. But if it is to be used for the threads that form the warp—that is, run lengthways of the piece—it is wound on a large wooden beam, probably four hundred threads being laid side by side and sized with a strengthening and preserving paste, before being transferred to the weaving-loom.

The Processes in the Making of Cotton Cloth of Many Kinds

If the yarn is to be used for something more elaborate than plain cloth, it may have to be bleached and dyed; and to facilitate these processes it is reeled into hanks, forty yards long, and the hanks are "bundled" by pressure into packages, usually of ten pounds weight.

Sewing-thread is not spun directly from the yarn, but several separate threads—generally four—are brought together and twisted into a sewing-thread, before being polished and wound on spools.

The weaving process is common to all textile fabrics, whether the patterns are plain or fancy, or the Jacquard loom is used. Goods go from the manufacturer to the bleacher, from the bleacher to the dyer, and from the dyer to the printer and finisher.

The bleaching process alone involves half a dozen treatments. First the cloth is singed to remove projecting filaments, and then washed; boiled with lime for eight hours, and washed; "soured" with sulphuric acid, and washed; boiled with soda ash for from six to twelve hours, and washed; passed through a solution of bleaching powder, and washed. Before cotton goods can be dyed they are as a rule passed through a solution of mineral salts with the effect of causing the dye to adhere to the fibre. Dyeing and calico-printing are chiefly carried on in the neighbourhood of Manchester and Glasgow.

Cotton has the questionable quality of lending itself to imitation of other materials, so that woollen, silk, and linen goods can be and are alike suggested in cotton fabrics, and the fibre is also used in combination with these other materials. Unmixed, it is woven into an enormous variety of goods, from plain sheeting to embroidery.

The Amazing Variety of Style and Design in the Cottons of the World

The common divisions of the fabrics are plain goods, such as printed cloth and sheetings; twills, with diagonal warp threads; sateen, fancy cloth, and Jacquard fabrics.

The names given to different types of cotton goods—pure cotton, imitation, or part cotton—are legion, and illustrate the amazing variety of style and design. As examples may be mentioned baize, bandana, bombazine, brocade, calico, cambric, canvas, chintz, corduroy, crape, cretonne, denim, dimity, drill, duck, fustian, gauze, gingham, moleskin, mull, muslin, nankeen, print, rep, twill, velveteen, shirting, sheeting, Mexican, T cloth, Wigan, double warp, Croydon, printing cloth, Jacconet, dhortie, scarf, madapollam, baft, Sarong, jean, jeanette, Oxford, Harvard, regatta, mercerised cloth, lace, lace curtains, matting, matelama, piqué, Bedford cord, oatmeal cloth, crimp cloth, grenadine, leno, lappet, zephyr, bobbin-net, Silesia, sateen, hollandette, lawn, batiste, serge, huckaback, galloon, butter-cloth, mosquito netting, khaki, cottonade, lasting, and brattice cloth.

Cotton may be spun into an almost incredible thinness. A pound's weight of raw fibre can be subjected to all the processes of preparation that have been barely

AN AVENUE OF SPINNING COTTON IN OUR GREATEST MILL

In the spinning-mule shown on page 347, which spins the best and finest yarns, the action of the machine is intermittent, the parts not working constantly in one direction. But in the ring spinning-frame, shown in this picture, the spinning goes on continuously without any stoppage or change of direction. This machine, photographed at Messrs. Horrockses, Crewdson, and Company's works, the great English cotton mills, spins the strongest yarns.

enumerated here, and then drawn out into a thread quite confidently of 84,000 yards; and a length of 160 miles has been reached in the attenuation of a single pound of prepared lint.

The story of the improvement of the machinery by which cotton is prepared for man's use is a particularly sad one, as it covers the days when men believed that machinery ruinously lessened the demand for labour. The use of cotton goods at all in England was for a time interdicted in the interest of the wool trade, the penalty for wearing calico being £5, *to be paid to the informer.* When the manufacture first gained a footing in the land the warp was by law confined to linen yarn.

The Doom of the Men who Turned Cotton into Gold

As invention became stimulated suspicion and persecution grew with it. Thus John Kay, the maker of the flying shuttle, was driven from the country and died in poverty abroad. Lewis Paul, who originated the principle of spinning by rollers, does not seem to have profited much by his ingenuity. James Hargreaves, the inventor of the "spinning jenny"—which, by the way, could deal with cotton only in a state of roving—was obliged to flee from Lancashire and restart business in Nottingham. The only prosperous inventor was Richard Arkwright, the Preston barber, who invented the "water-frame" spinning machine—so called because it was worked by water—and he removed from Lancashire to Derbyshire before he established the business which made him his fortune. Samuel Crompton, whose spinning "mule" —a combination of the machines of Hargreaves and Arkwright—was the greatest of all spinning machinery inventions, lived in old age on the subscriptions of sympathetic friends, after having lost the £5000 with which the Government of the day recognised his merits as an inventor.

The Great British Industry Built up by British Genius

Richard Roberts of Manchester, who made the "mule" self-acting; Edmund Cartwright, who introduced the power-loom, and was awarded £10,000 by the Government because he impoverished himself by his experiments; and Joshua Heilman, an Alsatian who invented the comber, and died soon after he attained success, have an honourable place in the history of the improvement of the complex machinery for the most complicated of manufactures.

With the exceptions of Whitney and Heilman, the experimenters whose improvements have hurried forward the prosperity of this highly specialised industry have all been Britishers—obviously as it should be, since there is no business in which Great Britain holds such an unquestioned pre-eminence, unless it be shipbuilding.

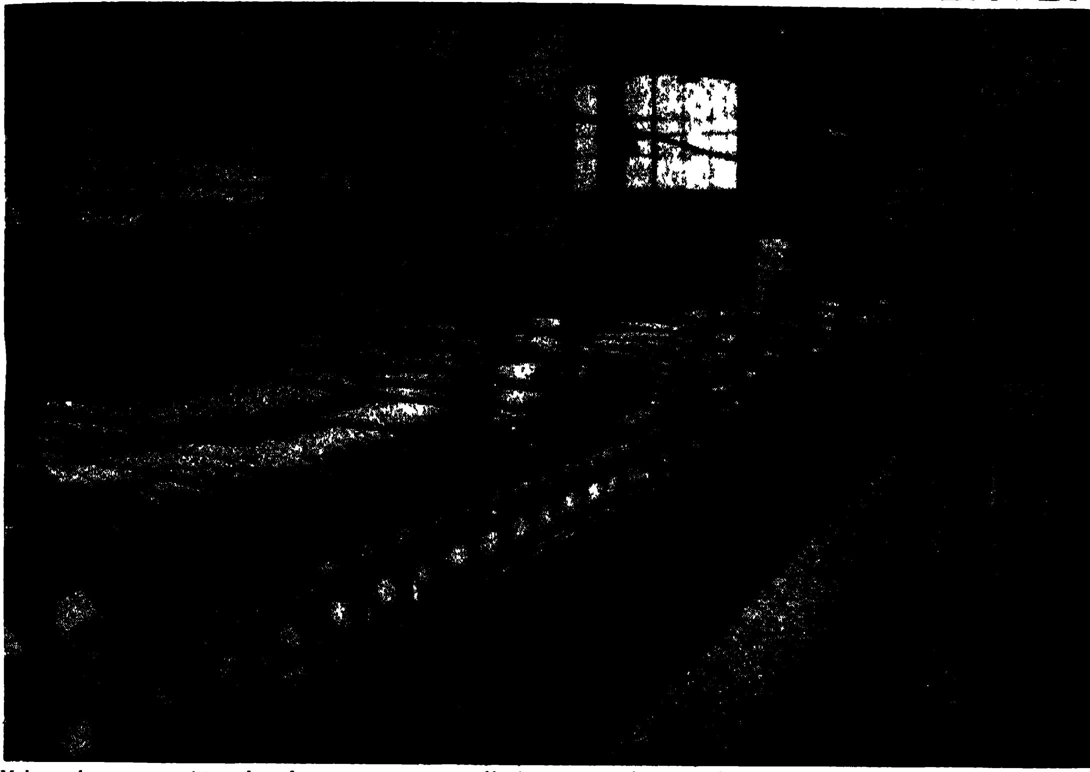
While it is true that the United States, Germany, India, France, Italy, and Russia have a vigorous cotton trade, largely to supply their own wants, England commands the open and neutral markets of the world, and in special lines sells largely even to these manufacturing countries. Our export of cotton yarn is five times that of Germany, and of piece-goods four times that of Germany, and more than ten times that of the United States. Our manufacturing power, as judged by the number of spindles, counted in millions, is as 56 against 39 for the whole of the Continent of Europe, 29 for the United States, and 10 for the rest of the world, so that approximately 42 per cent. of the cotton manufacturing power of the world is in British hands.

One of the Most Wonderful Examples of the Exchange of Goods that Commerce can Show

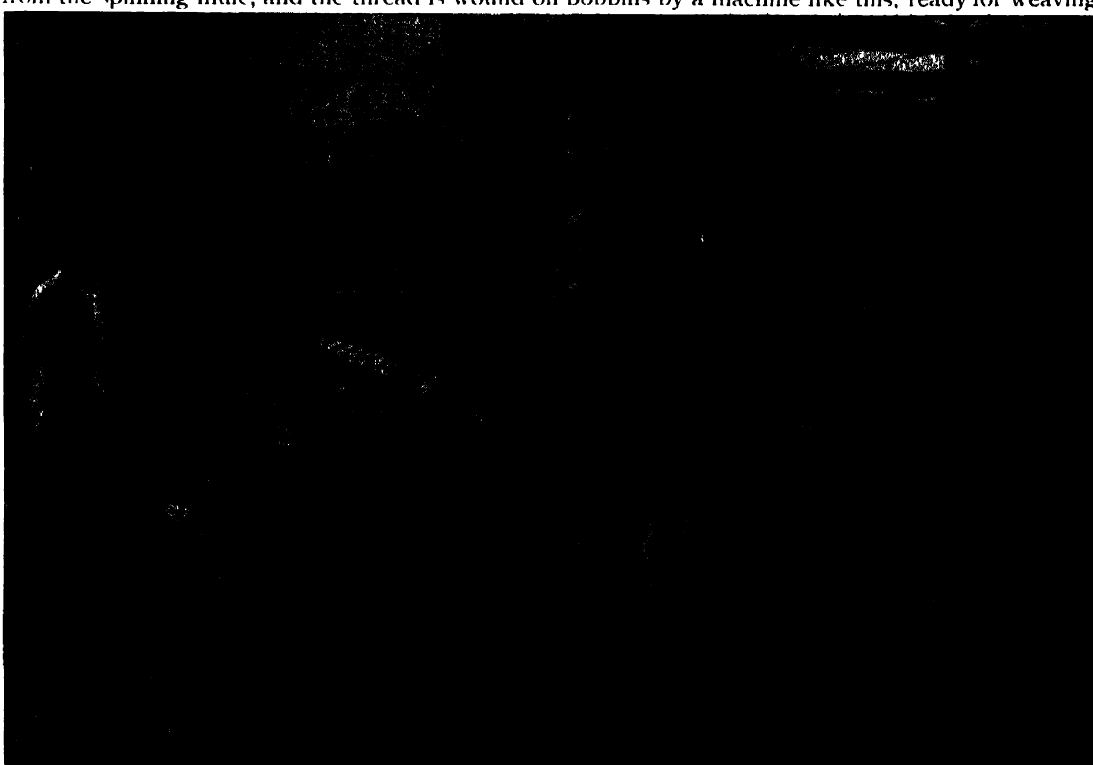
It is unfortunate that a business so closely identified with the prosperity of the British nation should in two respects be subject to serious criticism. One drawback —for which our country has no special responsibility—is the gambling on crops, which, under the euphemistic name of "futures," does much to unsettle a great industry, to the detriment alike of the cotton-grower and the manufacturer; and the other, for which we are responsible, is the number of women and children still employed in Lancashire in the trade, breaking up home life, and interfering with the natural conditions of family concord and interdependence under which the father is the adequate bread-winner and the wife ensures the comfort of the house.

The world's annual production of raw cotton—that is, the lint as it arrives in bales ready for the manufacturer to begin his long series of operations—reaches a weight of about four and a half million tons. Perhaps one-third of this does not leave the country where it is grown, for most of the cotton-growing regions have some amount of cotton manufactures, but the transportation and re-transportation of the rest—and, indeed, of the products of the whole of the world's cotton fields and spindles and looms—furnishes one of the most wonderful examples of universal interchange of goods that modern commerce can show. The

WINDING THE THREAD FOR THE WEAVER

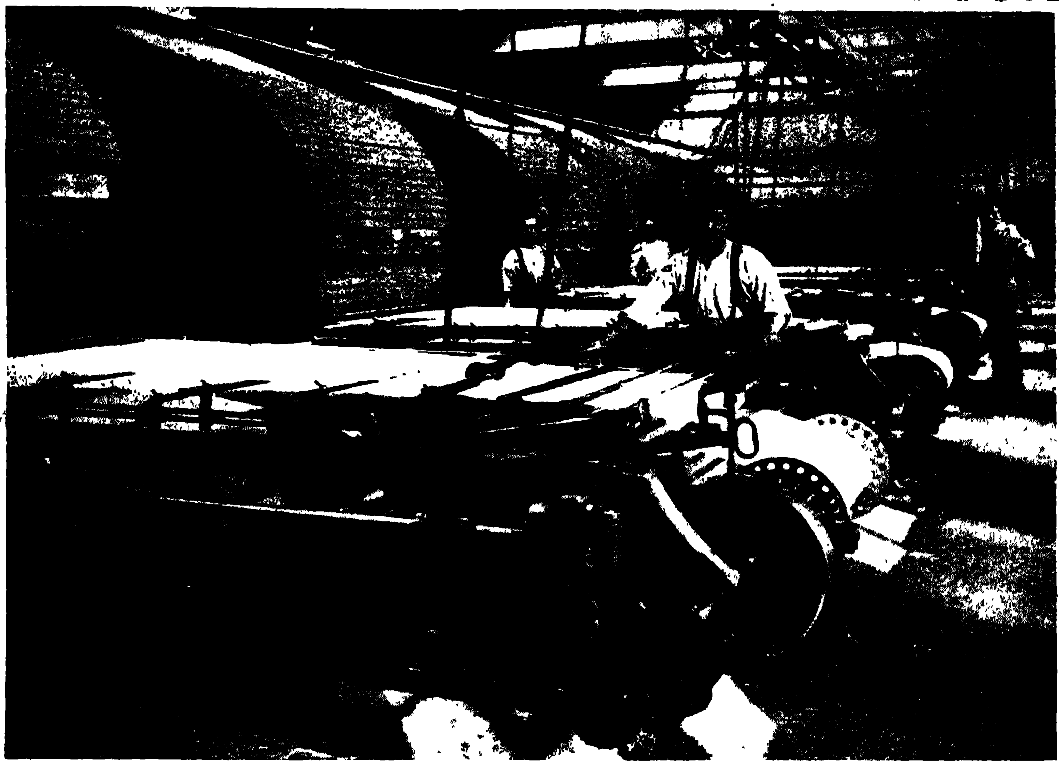


When the cotton fibre has been spun it is called yarn. The spools of yarn, known as cops, are taken from the spinning mule, and the thread is wound on bobbins by a machine like this, ready for weaving.



The bobbins are now arranged on large frames called creels, and a warping-machine takes all the threads from the bobbins and winds them side by side in regular order upon a roller as shown here.

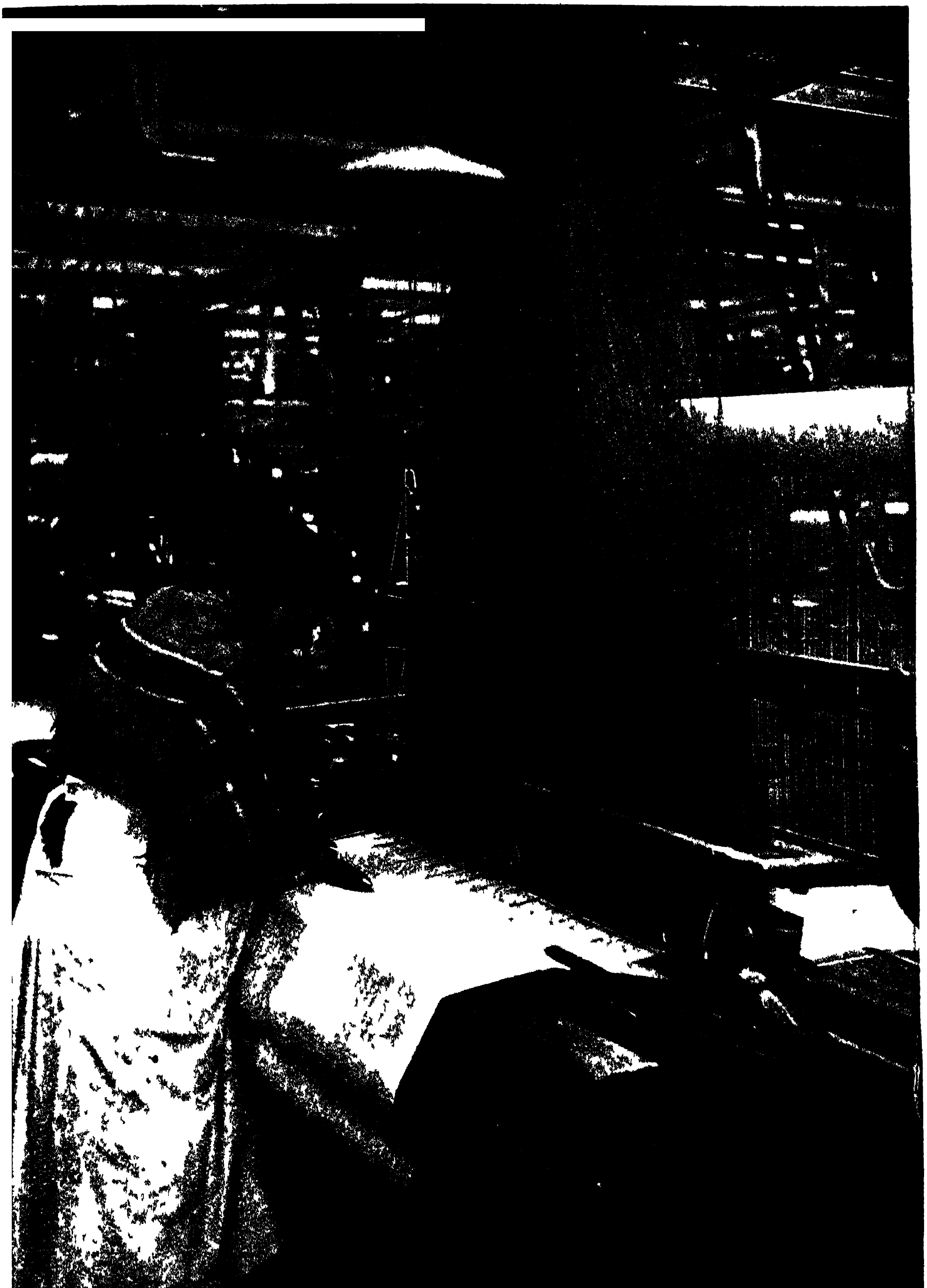
PREPARING THE WARP FOR THE LOOM



The threads of the warp are put in a bath of liquid-size to strengthen them, passing for this purpose through a slashing machine. Then the warp threads pass over hot cylinders, which dry them.

The warp, which is the foundation of the cloth into which the weft, or cross-threads, will be woven, is taken to a drawing-in frame, where a man passes the threads through a guiding-frame, ready for the loom.

WEAVING LOVELY PATTERNS ON THE LOOM



This is the Jacquard loom, which enables an ordinary worker to weave the most beautiful patterns. The perforated drum at the top produces the pattern, in much the same way as the perforated ribbon plays the pianola. The inventor of this loom was nearly killed by his infuriated fellow-workmen.

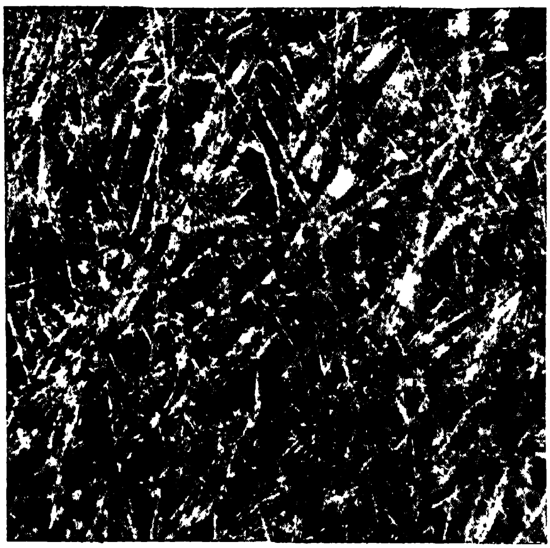
IN ENGLAND'S LARGEST WEAVING MILL

This shows what a weaving-shed is like. It is inside the largest weaving factory in England, that of Messrs. Horrockses, Crewdson, & Company, and the looms are seen stretching away in the distance.

Sheeting is made on very large looms like the one in this picture. As the cloth is woven it is wound on to a roller in front of the loom, and is then taken away to be folded by machinery.

iron work of the "Black Country," the steel goods of Sheffield, the woollen wear of the West Riding, the leather-made produce of Leicester and Northampton, the corn of the Canadian prairie, the fruits of the West Indies, Ontario, California, and the Levant travel far, and reach many races living under varied conditions, but the width of their dissemination, with, perhaps, the single exception of the knife, is but limited compared with that of the roll of cotton piece-goods.

The range of the cotton trade is the range of man's clothing. It is only the naked who are exempt from its fascination, and they because they are too remote to know the bright, light, and cool fabric, except, perhaps, as a curiosity in luxury and delight. The time is coming when fifty millions who wear no clothing worth mentioning will be clothed with cotton cloth, and when a hundred million more who wear but little will be draped in its dignifying folds. It is the one fabric which, by virtue of its cheapness, and its adaptability to all climates, for under-wear or over-wear, is destined for universal adoption.



THE COTTON FIBRE MAGNIFIED

One pound of this fibre can be spun into a thread 160 miles long. An average picker will gather a hundred pounds of fibre in a day, though some can pick twice as much.

Note, too, how it interweaves the lives of all diversities of mankind. The merry negro, Americanised on the cotton farm of Carolina or Florida, grows the flossy snow that gives work first to the hardy sailorman, and then to the keen-witted "operative" of Lancashire, and, through his machinery, to the engineering centres of Great Britain. All unaware of its origin on the black man's land, the secretive British farmer buys, by binding agreement with his landlord, so much "cake" for his cattle, that the fields of England may be manured by the cotton seed of another hemisphere. The fisherman of Quiberon Bay is brought up to Paris to warn the French Government that in making its tariff arrangements it must not disturb the balance of trade that allows cheap oil from New Orleans to be substituted for the olive oil of Italy, otherwise his trade in tinned-fish delicacies will be ruined. The vegetable butter and lard of the tropics not only cheapens the food of the British slum-dweller, but pleases the fancy of the vegetarian cook.

This forward flow of cotton products over the face of the civilised world is followed by a backward flow of enhanced value from the manufacturing centres over the earth, civilised and uncivilised; and the negro of the forest swamps of Western Africa barters his humble wealth for a gaudy cheap cloth which has its origin in the organised labour of men of his own race transplanted by force and cruelty a century ago across the dreaded ocean.

This expansive influence of the cotton plant, bringing all races into touch through its universal distribution, is balanced, however, by a restrictive influence. It is through the cotton trade that the modern factory system has been most completely, and perhaps deplorably, developed. The wave of cotton enterprise in cotton-spinning found English weaving a rural industry, and has brought it into the towns, or, rather, has made a town, dense, regular, mechanical, dull and soul-wearing, around every manufacturing site. And the most distressing problems of modern civilisation—the overthrow of home life through the employment of women, the presence of the child in the whirring factory, the declining physique of the cooped-up worker, the mortality in infant life, the ravages of tuberculosis, the grey monotony of existence, the loss of the ideal of living in joy and not in dolour—are all connected with this great industry more intimately than with any other, and naturally so at first, because it is the industry in which the use of machinery, mechanical order, organisation to the last word of economical efficiency, have been perfected. But the time is at hand when the greatest of all the trades in fabrics will realise that the aim of producing the best, cheapest, and most profitable roll of cotton cloth is not self-complete and satisfying unless the human material used in the process is left untarnished.

THE STUPENDOUS TRAFFIC WHICH OPENS THE GATES OF THE WORLD TO GREAT BRITAIN, AND UPHOLDS THE UNPARALLELED COMMERCE OF THE BRITISH EMPIRE

THE FIRST TRADING NATION

The Great Source of Energy upon which the Prosperity of Great Britain has been Built Up

THE IMPREGNABLE ROCK OF OUR COMMERCE

THE commercial supremacy of the United Kingdom is a remarkable thing. It is a supremacy the more remarkable because possessed by an island or group of islands of exceedingly small area, and of very limited natural resources. The forty-five million British people make their home on an area of but 120,000 square miles, which means that we have 375 persons to each square mile.

There is no more wonderful tribute to the activity of man than to consider that, in a long-developed country like our own, by far the greater part of the surface of the country has been laboriously worked over, yard by yard, and again and again, during centuries of time, and that what Nature provided has been shaped and reshaped until few are the spots which are not to some extent at least artificial.

The 77,000,000 acres of the British Isles are for the most part put to use. Some 48,000,000 acres, according to the Board of Agriculture, are under crops and grass, rather more than one-half being permanent pasture. There are something less than 1,000,000 acres of inland waters; 3,000,000 acres of forest and woodland; 13,000,000 acres of heathland and mountain; over 1,500,000 acres of bogs and marsh in Ireland. The remainder, some 10,000,000 to 11,000,000 acres, is either barren or occupied by towns and villages, roads, railways, gardens, and pleasure grounds.

The chief reproach which may be brought against our national economy is, perhaps, the small area devoted to the growth of timber. The culture of trees has been sadly neglected, and there is no other country in Europe which has such a small proportion of timber area. A Royal Commission in 1908 reported strongly in favour of national effort in afforestation, and, as we shall see when we come to examine the world's commerce in detail, the subject is certainly one which demands early and earnest attention.

From our nearly 50,000,000 cultivated acres we derive about one-half of such foods as can be raised in our climate, but there are, of course, many valuable foods which Nature forbids us to grow. Such commodities as tea, coffee, cocoa, sugar, maize, bananas, tobacco, have come to be regarded as next to indispensable, and they have become so commonplace that we scarcely realise that they have to be won by the difficult operations of commerce.

When we pass to the domain of raw materials we find ourselves even worse furnished than in regard to foods. Very little indeed of British work in industry is done upon purely native materials. Here, again, the commercial miracle has become an everyday, unregarded commonplace. Products foreign to our soil and climate, or which, if found or raised here, are given us in exceedingly limited measure, are everywhere built into our environment. Palace and cottage alike are largely constructed of imported materials. Our clothes, our implements, our machines, our instruments of sport and play, are as to the greater part made from stuff from oversea.

A very great part of our industrial work is done upon iron and steel. Fortunately, we possess very great supplies of native iron ores. Nevertheless, of our total consumption of iron ore in a year—about 21,000,000 tons—over 6,000,000 tons are imported. Even this fact does not bring out our real dependence upon imports in the matter of our great iron and steel trade. The iron ores which we import are, on the average, much richer

in metallic content than the ores raised at home, and, broadly speaking, about one-half of our production of pig-iron is based upon ores obtained by commerce from beyond the seas.

When we turn to other metals we find that the British economic position is a curious one. We do an enormous amount of work in the metal trade, yet we are very poor in metals other than iron. We have fair supplies of tin, although not nearly enough for the work we have to do, but the products of our native zinc, copper, and lead mines are very poor.

What Would Happen if British Commerce were to Cease for a Few Months

If we can imagine that the whole of our British commerce were to cease for a few months, our brass trade would close down, our production of galvanised iron and other products demanding zinc would cease, and large sections of our population who live by the metals would cease to earn wages.

The facts on this head are of such great moment that a study of the following significant table is necessary to the understanding of our dependence on oversea trade.

A YEAR'S PRODUCTION OF METALS

THE BRITISH PRODUCTION OF METALS, FROM BRITISH ORES ONLY, CONTRASTED WITH THE WORLD'S PRODUCTION OF METALS IN 1909.

The figures are given in metric tons of 2204 lb.

Metal	U.K.	The World
	Tons	Tons
Iron	4,900,000	60,000,000
Copper	500	893,000
Zinc	4,000	856,000
Lead	23,000	1,050,000
Tin	5,300	117,000

It will be seen that if British work were done upon British material only British manufacturers would occupy an insignificant position in the world of trade.

The Access to the World's Mines which Makes us a Great Metal-Working Nation

We produce, from ores got out of our own mines, less than 5,000,000 tons of iron, a mere 500 tons of copper, some 4000 or 5000 tons each of zinc and tin, and 23,000 tons of lead—figures which, when contrasted with the total output of the world, are almost negligible. Commerce, however, provides us with access to all the mines of the world; and Britain ranks, by reason of commerce and commerce alone, as one of the three greatest metal-working nations.

With regard to other branches of the mineral world, we are well supplied in slate, sandstone, potter's clay, and limestone, and we have also good supplies of pyrites, but these things, though valuable, could not be the basis of a great and varied industry.

But, fortunately, while we are so badly off in native minerals as a whole, we have exceptionally good supplies of the mineral which, as we have already seen, confers such magnificent advantages upon the countries which own it. *We have splendid coal.* According to the estimate of the last Royal Commission on Coal Supplies (1905), the United Kingdom possesses, in seams of one foot thick and upwards, and not deeper than 4000 feet from the surface, 101,000,000,000 tons of the indispensable source of large-scale power.

When we turn to the raw materials of the textile industry, we see that the British Isles are much worse off in regard to these even than in regard to metals. For a number of important fibres we are entirely dependent upon oversea sources. We cannot grow cotton, or hemp, or jute, and we cannot grow silk competitively. We grow a small amount of flax, but find it necessary to have large recourse to imported material.

The Dependence of Industry upon Commerce for the Means of Work

Even with regard to wool, we are no longer, as in ancient days, independent of commerce. Time was when England not only exported wool, but had such a monopoly in the wool supply that she could levy an export duty and make the foreign buyer pay it, for he had to buy our wool or go without wool. Our woollen and worsted industries have, however, in the last four or five generations rapidly outdistanced their native wool supplies. The following facts are at once a tribute to the British manufacturer and a proof of our dependence upon commerce for the means of work.

WOOL USED IN BRITISH WOOLLEN AND WORSTED INDUSTRIES

The figures include hair, but not shoddy.

Year	Imported Wool	Native Wool	Total
	lb.	lb.	lb.
1775	2,000,000	80,000,000	82,000,000
1800	10,000,000	100,000,000	110,000,000
1875	200,000,000	151,000,000	351,000,000
1900	382,000,000	116,000,000	498,000,000
1910	506,000,000	106,000,000	612,000,000

These figures, derived from the official records of the Bradford Chamber of Commerce, give us a picture of an industry which

has grown and flourished upon imported material. We see that the great textile factories of Yorkshire and elsewhere would, without the operations of commerce, be reduced to very small dimensions. It is true that, if foreign and colonial wool could not be obtained, more wool would be raised in the United Kingdom, but it could only be at an advanced price, which would mean that the British consumption of woollens and worsteds would greatly fall; in no case could we raise all the wool we need. It is not merely that we have to clothe ourselves; we have to maintain a very large export trade in woollens and in garments, in order to earn the supplies without which our mills could not be run.

We have already referred to timber. Nearly the whole of our work upon wood is done with imported materials. Here is a matter in which we can to some extent help ourselves, and become less dependent upon oversea supplies. In any case, however, we could not grow all the timber we need, and many valuable woods cannot be raised at all in our climate. Moreover, if large-scale British afforestation were at once undertaken, many years would elapse before the timber could be brought to market.

The Vast Supplies of Raw Material that Pour into our Workshops

In respect of many important miscellaneous materials, we are dependent wholly, or almost wholly, upon the shipping trade. Indiarubber, gutta-percha, asbestos, ivory, many valuable mineral and vegetable oils, have to be earned and brought from oversea.

If we look at the whole body of our imports of raw materials and articles mainly unmanufactured, from ores to fibres, and from timber to wood-pulp, we find that our importations are enormous. The figures in the following table show them for three periods.

U. K. IMPORTS, FOR HOME USE, OF RAW MATERIALS AND ARTICLES MAINLY UNMANUFACTURED.

1900	£139,000,000
1905	£145,000,000
1910	£198,000,000

These figures relate solely to materials actually used in the United Kingdom, deduction having been made for such materials as are brought in and re-exported in the merchant trade. Further, it should be remembered, they are exclusive of such articles as crude copper, ingots of tin, leather, and many other materials of industry which are imported in a manufactured form. Even so, they are an eloquent expression in concrete of the general truth we have been examining. British work is based upon products which we can only secure by means of commerce with other nations or with the British dominions and possessions beyond the seas.

In view of the remarkable facts which we have examined, how is it that Britain is the home of a great, a populous, and a wealthy people? We have already indicated the answer to this question, which goes to the root of the British economic position.

The Power that Cannot go to the Factory, but to which the Factory Must Come

The possession of coal not only means the possession of power, but it means the possession of power *which can only be exercised commercially in the area where the coal is found.* Economically, power cannot be exported or imported. Where it is found on the world's area—we speak, of course, of power within the limitations described in the last chapter—there it must be used, as far as competitive manufacturing is concerned.

The explanation of the immobility of Nature's power supplies is of the greatest economic importance. Upon the immobility of water-power it is not necessary to dwell. Suffice it to say that science has not yet taught us how to conduct electricity manufactured from water-power to any considerable distance economically. *With regard to coal, the main source of energy at present utilised by man, it is its bulkiness, and the consequent dearness of transport, which make its power immobile in relation to competitive industry.* It is perfectly true that coal can be exported from a British port to remote regions, and that at the place to which it is taken the coal can be used exactly as at a point within a few hundred yards of its origin. But in the transportation the price of the coal is so greatly raised that the manufacturing done with the transported coal cannot possibly compete in price with the goods made in the coal area.

Why no Colony Could Rescue the Motherland if Her Coal Supplies Failed

It is not too much to say that the fact just recorded lies at the very root of industry and commerce at the beginning of the twentieth century. It explains why some nations are industrially great, and why others are industrially small. It means that if we take a map of the world and trace the position of the world's great coal-mines, we have an infallible guide to the location of the world's great industries. It means also that one nation cannot, by exporting coal, contribute much to the industrial greatness of another nation, or enable another nation to compete with itself by reason of coal bought

from itself. It means that the United Kingdom cannot, by exporting coal to, say, Jamaica, make that island a great industrial centre. It means, again, that if we imagine the Mother Country depleted of coal, a colony possessing coal could not come to the commercial rescue of the Motherland by exporting coal to her shores.

The Wonders that Coal has Worked for Modern England

For the British people coal has worked marvels. We cannot express what the discovery of the value of coal meant to British wealth and development better than was done by Jevons in his great work on coal :

> The history of British industry and trade (he says) may be divided into two periods, the first reaching backward from about the middle of the eighteenth century to the earliest times, and the latter reaching forward to the present and the future. These two periods are contrary in character In the earlier period Britain was a rude, half-cultivated country, abounding in corn, and wool, and meat, and timber, and exporting the rough but valuable materials of manufacture Our people, though with no small share of poetic and philosophic genius, were unskilful and unhandy ; better in the arts of war than those of peace ; on the whole learners rather than teachers. But as the second period grew upon us many things changed. Instead of learners we became teachers ; instead of exporters of raw materials we became importers ; instead of importers of manufactured articles we became exporters. What we had exported we began by degrees to import, and what we had imported we began to export

The remarkable change in our commerce in wool, to which we have already referred, is but one concrete illustration of the great generalisation that coal made modern Britain. It is difficult at this date to realise that at a time not long removed the British Isles were regarded by the rest of the world as a source of raw materials, a place from which Continental manufacturers drew raw wool to be worked up into cloth and resold to us in its finished state.

How Coal Inspired the Great Inventions of British Engineering

If we were to name the most striking illustration of the truth that coal-power is immobile, we should point to the fact that even within the narrow confines of the United Kingdom itself the greatest backwardness is found at places distant from the coal-mines, or away from points to which coal can be transported cheaply. In such places as in Wiltshire, or as in the West of Ireland, the lowest wages of the country are paid and the least wealth is to be found.

It is of the deepest interest to observe, in passing, that the great British engineering inventions were prompted and stimulated by the possession of great coal-mines. British coal-getting was checked by what for long seemed an insuperable difficulty, the flooding of the workings. The necessity arose of draining mines. That necessity was the mother of the steam-engine. Savery's steam-engine was devised solely to pump mines. Newcomen's atmospheric steam-engine, in which the charge of steam was exhausted by a jet of water beneath the piston, and the atmospheric pressure used to depress the piston and so raise the other end of a beam attached to the piston, was also a mining device. These inventions, in their turn, reacted upon mining, and by making coal much cheaper gave a tremendous impetus to industry and trade.

It is particularly interesting to recall that George Stephenson, who by inventing the steam locomotive, practically in its present form, multiplied a thousandfold the possibility of trade, was a colliery engineer, and that one of the things he wished to do was to facilitate the transport of coal.

George Stephenson's Picture of the Lord Chancellor Sitting on a Bag of Coals

It was George Stephenson also who said : "The Lord Chancellor now sits upon a bag of wool, but wool has long ceased to be emblematical of the staple commodity of England. He ought to sit upon a bag of coals."

The cost of transporting many of the important raw materials is heavy, but the element of freightage is not so great in regard to them as in regard to coal. Consequently, it always pays to take raw materials to coal, but it does not pay to take coal to raw materials. As an economic result, the coal-mine becomes a magnet for industry, and the country which owns it possesses an indisputable advantage over coal-less lands.

In the United Kingdom we have fine supplies of potter's clay in Cornwall, and fine supplies of coal in the Midlands. It pays best to take, not coal to the clay, but clay to the coal ; and the kaolin of Cornwall is exported from Cornwall to Staffordshire or to the Continent of Europe. Very little is used near the clay-works. If Cornwall possessed coal, it would be the seat of one of the finest pottery industries in the world. If that is the case within a coal-owning country, we can easily imagine how the bulkiness and weightiness of coal tells in transport over longer distances. Good coal can be shipped from Newcastle at about 9s. per ton, f.o.b. (that is, including cost of

THE LAND OF THE BRITISH ISLES

There are 77,000,000 acres in the British Isles, of which 48,000,000 are crops or grass, 13,000,000 are heathland and mountain, 3,000,000 are forest and woodland, 1,500,000 (in Ireland) are marsh and bog, and about a million are inland water. The rest is made up of towns, villages, roads, railways, and so on.

delivery on board ship); freight to the Mediterranean raises its value to 15s. or 16s. a ton at Genoa or Marseilles. Take the same coal to the West Indies, and it is doubled in value. Argentina possesses fine wool. If she imported British coal with which to run mills to work up the wool, the resulting cloth could not possibly compete with cloth made out of Argentine wool manufactured in Yorkshire in a coal area.

Given a country great in coal, but deficient in materials, what is the great condition of successful trade, other things being equal? It is, of course, access to the world's raw materials. We now come to inquire how Britain stands in respect of this important factor.

Fortunately, the British Isles have many natural advantages in respect of geographical situation and seaboard. Perhaps no country occupies a more central position in the commercial world. No part of the interior of Britain is more than about one hundred miles from tide-water. Our coasts possess many fine harbours. Not only do we possess splendid coal, but some of our most important coalfields are close to fine ports or intersected by the sea. Given an efficient railway system, and such advantages can be utilised to draw economically from all parts of the world the materials of British work.

The success of Britain in obtaining by commerce the materials which she lacks is a matter of much interest and importance. In this all-important matter of obtaining cheap and abundant raw materials the magnificent British mercantile marine plays a part which is little understood. Here, again, we are confronted with the great value of coal. *It is our export trade in coal which makes our shipping profitable.* The general position is that we chiefly import food and raw materials, and chiefly export manufactured articles. We shall have occasion to review the facts in detail, but at this moment it is only necessary to set out the broad Board of Trade analysis. The figures for 1910 are set out in the table given below. British sea-borne commerce in 1910 is seen to be: Total imports, £678,500,000; total exports, including exports of imported stuff, £534,400,000; grand total, £1,212,900,000. Now let the totals of the various great categories be examined. It will be seen that of the £678,500,000 of imports, as much as £519,000,000 consisted of food or raw materials; while of the total exports of £534,400,000 as much as £370,400,000 consisted of manufactures, and only £116,700,000 of British and foreign materials.

Consider these facts in relation to our shipping. Food and raw materials are bulky substances, forming large cargoes. Manufactured goods, on the other hand, have small bulk per unit of value, and consequently they afford, even when shipped in considerable quantities, comparatively small cargoes.

The general position is, then, that ships coming to our shores find great cargoes in food and materials, while ships leaving our shores find fewer materials for shipment, and a large value of manufactures which does not bulk for sufficient cargo to fill their holds. If this were the whole of the story, it is obvious that many of the ships bringing food and materials to our shores would have to go outwards in ballast for want of cargoes. That would mean that the inward freights on food and materials would have to be heavy in order to pay for both the inward and outward voyages of the ships, and the price of food to the British consumer, and of materials to the British manufacturer, would be appreciated.

It is here that coal again comes to our economic assistance. We have large coal exports, and coal is a bulky and weighty article. Consequently, although our exports of British raw materials were, as will be seen by reference to the table, only £53,400,000 in 1910, this figure stands as to as much as £37,800,000 for coal. The quantity exported for this money was 64,500,000 tons, but this does not include the coal in the ships' bunkers; the bunker

A BROAD ANALYSIS OF BRITISH COMMERCE IN THE YEAR 1910

Category	Total Imports	Exports of British Produce	Exports of Imported Produce	Total Exports
	£	£	£	£
Food and Tobacco	257,800,000	26,100,000	12,900,000	39,000,000
Raw Materials	261,200,000	53,400,000	63,300,000	116,700,000
Manufactures	156,900,000	343,000,000	27,400,000	370,400,000
Miscellaneous	2,600,000	8,100,000	200,000	8,300,000
Total	£678,500,000	£430,600,000	£103,800,000	£534,400,000

coal shipped for the use of steamers engaged in oversea trade was nearly 20,000,000 tons more. It will at once be seen that this exportation of 64,000,000 tons of coal furnishes our shipowners with just the bulky and weighty outward cargo needed to redress the balance—from the cargo point of view—between imports and exports.

Thus coal is seen to lie not only at the root of industrial strength, but, in the case of the United Kingdom, to make shipping profitable, and to reduce the British manufacturer's cost of obtaining materials.

But how is it that so many million tons of British coal are exported in a year if it is not profitable to import coal for industrial purposes? The answer to this question is that the coal we export is mainly shipped away to foreign ports for the use of steamships, which have no option but to replenish their bunkers where they can. The exportation of British coal is indeed a symbol of the growth of the world's steamships, and mainly of British steamships.

Such are the main factors of the British economic position. They are governing factors only partly under the control of man. But while Great Britain cannot, by taking thought, add stores of coal to her mines, or call to her aid the immense advantage of such wonderful natural resources as are possessed by the United States, it is her manifest duty carefully to conserve her power supplies, assiduously to train her population in the arts, and steadfastly to direct all her powers to the most economic exploitation of the means of wealth which underlie her greatness and her progress. A complete understanding of the dominating and essential elements which we have considered is necessary alike for the safety and guidance of British commerce and British statesmanship.

"THE RUSH OF COMMERCE TO TAKE POSSESSION OF THE VAST UNOCCUPIED SPACES OF THE WORLD"

LOVE THE CONQUEROR LEADING CAPTIVE THE LEADERS OF MANKIND

This splendid picture, representing Cupid leading the wise and great of all ages to his altar, is painted by Mr. Byam Shaw, and is reproduced here by arrangement with Messrs. Dowdeswell and Dowdeswells, the publishers of the large engraving.

ONE MAN AND ONE WOMAN

The Evolution of Marriage and its Development from Savage Forms into a Sacred Institution

THE UNBREAKABLE BOND OF MARRIAGE

The curious saying about marriage still current among us—

> Change your name and not the letter,
> You marry for worse and not for better,

is the most ancient marriage law now existing. It can be traced in various forms among all the peoples of the earth, with the exception of a few very low savages, and they probably have only lost it on being broken up and disorganised by conquest.

The old English rhyme may seem to be merely a meaningless superstition. Certainly few of the millions of our countrywomen who hand it on to their daughters have any knowledge of its significance. In our present state of society it has, indeed, become emptied of importance, but in the savage communities of Australia, North and South America, and part of Africa it is connected with a wonderful advance in human thought. It is a vestige of a strange and intricate system for preventing marriages between persons closely akin.

Of course, our remote ancestors were not ruled by the saying in its present form, for the very good reason that they could not spell. The superstition about wedding anybody whose name begins with the same letter is merely a modern substitution for a now-forgotten set of complex rules forbidding marriages between members of the same clan. All this is a curious example of race-memory. We feel it is not sufficient to forbid a Hawke from marrying a Hawke: there were many other persons with different names whom a Hawke might not make love to or marry. But we cannot remember the system, so we invent the nonsense about the danger of wedding somebody whose name begins with the same letter.

It is an axiom in geology that by studying the past we can understand the present, and by studying the present in the light of the past we can discern the forces which are shaping the events of the future. But in many of the problems of society we are able to study the present in the light of the present. We have only to look carefully at the black-fellows of Australia, for example, in order to understand the meaning behind our apparently meaningless superstition about marriage. In this way we shall obtain not only light on the past ancient marriage law of our own race, but suggestions for the future development of the latest of modern sciences—the science of producing the best kind of human beings.

Let us take one of the best-known of Australian tribes, the Kamilaroi of New South Wales. This tribe is divided into two clans, which are named Dilbi and Kupathin. These two clans are again sub-divided into two castes. The Dilbi is divided into the castes of Muri and Kubi: the Kupathin is divided into the castes of Kumbo and Ipai. The tribe possesses six totems. These totems are sacred animals—the kangaroo, the opossum, the lizard, the emu, the bandicoot, and the black snake. The tribe is further divided into six groups, and each of these groups has its special totem. The tribe is thus split up as this table shows.

	Castes	Totems	Clan	Castes	
Dilbi	Muri Kubi	Kangaroo Opossum Lizard	Kupathin	Kumbo Ipai	Emu Bandicoot Black snake

Every member of the tribe has his or her own clan, caste, and totem—these come down by descent. Now, all these divisions are marriage divisions. Men and women must wed always outside their clan, outside their caste, and outside their totem group. Thus, a man of the Dilbi clan must marry

a woman of the Kupathin clan. If he is of the Muri caste, he must take his wife from the Kumbo caste. If his totem is the lizard, he must choose an emu, bandicoot, or black snake wife. Let us suppose he marries an emu woman, then the children are emu children. They enter the Kupathin clan and belong to the Ipai caste. They therefore have to marry into the Kubi caste of the Dilbi clan, and their partners must be taken from kangaroo or opossum men and women.

Dim Glimpses of Scientific Truth among Savages who can Count only up to ten

Among the Indians of North and South America the system becomes more complicated. Some of the tribes are divided into ten divisions—clans, castes, classes, and sub-classes, with a bewildering variety of totems. Among the black-fellows of Australia there are some tribes with eight divisions; and men of science are amazed at all this curious and intricate organisation of preventive inter-marriage. Nothing so effectual obtains among civilised peoples; and there is rather a general tendency to deny that the lowest savages possess sufficient intelligence to construct so marvellous a system of marriage customs.

It looks very much as though they bestow on their children the careful forethought which we only give to breeding champion cattle and racehorses, fancy dogs and prize fowls. It is said that some of the Australian black-fellows can only count in words up to ten; and even Herbert Spencer was inclined to think that they knew little more than a dog about the way in which children come into the world. Recent research, however, shows that the black-fellow is well aware of what he is doing by his primitive system of eugenics. He long since discovered what Darwin proved by his remarkable study of the self-fertilisation of plants and the in-and-in breeding of animals.

Savage Belief in the Council of Chiefs that was held after the Creation

The Australians have a tradition that, after the Creation, fathers, mothers, sisters, brothers, and others of the closest kin intermarried promiscuously, until the bad effects of these marriages became manifest. A council of the chiefs was then assembled to consider in what way the evil might be averted, and the result of their deliberations was a petition to the Good Spirit. In answer to the petition, the Good Spirit ordered that the tribe should be divided into branches, distinguished one from the other by different names, after objects animate and inanimate, such as dogs, mice, emus, rain, and so forth, and that the members of any such branch should be forbidden to marry other members of the same branch.

Seeing that the Australian black-fellow understands clearly the full effect of his marvellous marriage system, we may take it that he has much more intelligence than some white men fancy. His legend, however, does not explain how the law of outbreeding came into existence. It would seem as though the totem grouping were the most primitive form of the tribe; for the totem is still the strongest bond among the natives of Australia. Two kangaroo men, for instance, belonging to hostile or foreign tribes, regard themselves as brothers.

The totem group is practically the unit for many social purposes. If an emu man has killed an opossum man, it is the duty of all the opossum men to avenge the death of their totem brother. And, according to the rules of savage justice, all the men of the same totem group as the murderer are guilty of the murder; so the avengers kill the first emu man they meet. In the same way totem brothers help each other in abducting a woman, in attacking an enemy, and in defence. It is not generally a question of blood relationship, for a totem brother may belong to a hostile tribe.

The Curious Custom which perhaps gave the children "Beauty and the Beast"

There is much evidence, however, in support of the view that the totem group was originally a family group. The American Indians, indeed, still regard the totem as the ancestor of the entire totem group. This quaint anticipation of the theory of the animal origin of man appears to have inspired many of the strange animal myths so common among barbaric and even civilised races. "Beauty and the Beast" is probably a totem myth; and so also are the tales of Jupiter descending to earth in the form of a bull, a swan, and an eagle.

By means of scraps of folk-lore and legend we are able to trace the existence of totem grouping among practically all the races of the earth. The only peoples among whom it cannot now be discerned are the broken and scattered Veddahs of the forests of Ceylon, and perhaps some disorganised tribes of Fuegians. These seem to have gone back to the family group; and it is very likely that their present practice of closely inter-marrying is a temporary accident, which, if not remedied, will sweep them away with the vanquished

THE PROUD BULWARKS OF BRITANNIA

The foundations of national glory are set in the homes of the people. They will only remain unshaken while the family life of our race and nation is strong, simple and pure. —King George V

Bushmen and the disappearing Hottentot of South Africa, both of whom also took to marrying with kinsfolk.

By tracing the original totem group back to the scattered families which existed before tribal custom originated, we may perhaps carry the law of marrying out of the group into an almost prehuman stage of culture. It is supposed that mankind in the brute stage was governed by a rude primal law.

In those far-off days, the group consisted, it is conjectured, of one adult male, a number of females, together with the young of both sexes. As the young males came to maturity, they would be expelled from the group by their sire, as is the case with cattle and other mammals. They would then wander about, as the young males of some existing species do, in bands of a dozen or more. At the marrying season of the year, however, the strongest of them would engage in single combat with the lord of some group, and either kill him or drive him, like a rogue elephant, to end his life in lonely ferocity.

The First Law of Marriage—"Thou Shalt Not Marry Within the Group"

Then, on this theory, as human feelings developed in the ape-like man, and as the children required a longer time to come to their full powers of mind and body, the feelings of maternal love increased in the mothers. They kept their children with them, and this led at last to some of the youngest males being allowed to remain in the family group on attaining maturity. The sire retained his sovereignty over all the females in the group, and so the young male had to win a mate outside the family.

Thus originated the primal law, "Thou shalt not marry within the group." This law was first enforced by the superior strength of the jealous sire, but in the course of time it came to be a traditional rule of conduct, with almost the power of an instinct. Such is the ingenious theory worked out by Mr. J. J. Atkinson and Mr. Andrew Lang.

Defective though it is in some particulars, it constitutes the only working explanation we have of the origin by natural means of the primal law of marriage. It does not seem likely that the system of forbidding inter-marriage was, as the Australian legend pretends, a late invention of the human savage. If there had been inter-marrying of near relations from the earliest times, it would be difficult to discover by what means the general strength and health of body had been maintained and developed. No doubt there may have been aberrant forms of marriage in the very earliest ages, but the offspring would be wiped out by the stern process of natural selection.

On the other hand, as Professor Stanley Hall recently pointed out, there seems some ground for thinking that the myth of the fall of man is founded on a dark and terrible event in the history of marriage.

Strange Facts from the Savage World which Throw Light on the Past

It is probable that very early in our history man was kept in a straight course, in regard to the union of the sexes, by the fact that he was able to breed only in one brief period of the year. The family group was then held together by the care the children required, and the natural affection which they called out in their parents.

Vestiges of a human marrying season in primitive times can still be discerned. The man-like apes begin to mate when fruits are plentiful, and there is no reason for excluding the ape-like man from the law which prevails in the animal kingdom. It is true that the whale, the elephant, some rats and mice, and several of the lower monkeys are able to obtain so rich and constant supply of food that they never really want, and, as a consequence, they have no fixed period of mating. But the animals which are the nearest relations to our primitive ancestor, marry only in a certain time of the year. Moreover, the presumption that our half-human and perhaps earliest human forefathers followed the general rule is supported by some strange facts.

Some rude savages are stated to have, even now, an annual marrying time. Thus it is alleged on good authority that the wild Indians of California, who are among the very lowest of existing savages, have their regular marrying seasons.

The Beginning of the Spreading of Population all over the Earth

This statement is confirmed by another observer, Mr. Stephen Powers, of the United States Geographical and Geological Survey Staff, who says of these Indians that "spring is a literal Saint Valentine's day with them, as with the natural birds and beasts of the forests."

In many parts of the world, tribal marriage feasts are still held in the spring months; and popular customs in England and Germany and other European countries indicate that similar festivals were held there in ancient times. And at the present

day there is still, even in civilised countries, a periodical fluctuation in the birth-rate.

Man has thus gone through the same transition as certain domestic animals. In Southern countries the goat and the ass pair throughout the year; the domestic pig—whose supply of food is also assured—now pairs twice a year, while its wild relations have only one mating season; and some cage canaries have now been observed to lay eggs in both autumn and winter. Very likely it was when man became a meat-eater as well as a fruit-eater that he escaped from his restricted marrying season. But the development of this power, which has enabled him to spread over all the earth, must have taken place gradually; and in favourable circumstances it might have at once made for progress in every direction. For with it man's emotional nature expanded, and this in turn added a new stimulus to the growth of his intellectual faculties. He was able to multiply more rapidly, and the larger number of his offspring urged him to greater exertions and inventions as a hunter.

The Natural Forces that Strengthen the Modern Marriage System

When, however, man won the extraordinary power of being able to marry throughout the year, he seems to have misused it, and checked his physical and intellectual growth by wild indulgence. Some men of science are inclined to think that the intellectual powers of the negro races are still permanently injured in this way. Mankind, happily, succeeded in slowly regaining some of the ground it had lost, by surrounding everything connected with the union of the sexes with fearful taboos and menacing superstitions. Nearly all modern savages regard their women as mysteriously dangerous creatures; and their religious marriage rites are performed with the object of lessening the peril of living with a wife. The ancient superstitious fear of woman is one of the chief causes of her social degradation in the lowest stage of culture; but it must be remembered that this degradation was, in its origin at least, a roundabout means of saving the race.

And now, having dealt with the interesting but difficult problem of the origin of the magnificent system of preventing intermarriage which has done so much to benefit mankind, let us endeavour to trace the development of the institution of marriage. Among nearly all the lowest savages, a man usually has only one wife. This seems due mainly to economic causes. In very low stages of society no distinction of class exists; the accumulation of wealth is impossible; and as life is principally supported by hunting, the labour of women is not of very high order.

All over the world there are natural forces that tend to restrict a man to one wife, and a woman to one husband. The sexes are generally about equal in numbers: this makes everywhere for single marriages.

The Marriage Customs of the Peoples of the East

Thus it comes that peoples and nations notorious for their polygamous tendencies are seen to be, on closer study, usually married in single couples. In India, for example, more than 95 per cent. of Mohammedans are wedded to one woman. In Persia only two men out of every hundred enjoy the doubtful luxury of a plurality of wives. The mass of the Hindoos are married singly; and among the labouring classes in China, also, it is rare to find more than one wife to one man. It is a mistaken opinion that in what we speak of as a polygamous society most men have more than one wife. The relative numbers of the sexes forbid the arrangement being extended to the whole population; really only the wealthier can indulge in several wives, the poorer having to be content with one, or often none.

As we shall see when we come to deal with the problem of the proportion of the sexes, there are certain factors which at times seriously disturb the equality in the number of young men and women. These disturbances produce grave disorders in society, and sometimes lead to the establishment of abnormal and unhealthy customs of marriage. Polyandry, or the marriage of one woman to several men, is, for example, found in Tibet and India and elsewhere.

The Only Human Feeling with a Single Absorbing Aim

But as we now only wish to trace the main lines of development of the union of the sexes, we must keep in view the forces that make for progress. Chief among these is the passion of love. True love may be said to be a real monogamous instinct. It seems to be the only human feeling with a single absorbing aim. The feeling of fellowship is by its nature diffused; even a mother's affection allows a plurality of objects; revenge does not always desire to have but one victim; and the love of domination needs many subjects. The greatest intensity of love, on the other hand, limits the regard to one person. In the imagination of the lover, the beloved acquires an immeasurable

superiority over all other men or women. No doubt in its beginnings the special passion of love may turn upon a small difference of liking, but such differences are quickly magnified by the wonderful effect of emotion upon the imagination. A lover's thoughts and feelings act and react until their object is distinguished in a transcendent way from all other members of the same sex.

The Only Native American Race which has Given its Women Political Power

This absorbing passion is not confined to men and women of civilised societies. It is found among savage peoples, and among birds, and some of the lower animals. The love-bird, for instance, rarely survives the death of its mate, even when supplied with a fresh and suitable companion. When love is allowed free play, and is not degraded, the lowest savage is not only remarkable for the purity of his marriage customs, but he is nobly distinguished for the high position to which he raises his women. Among the Red Indians, for instance, the Iroquois never marry more than one wife, and they are the only native race of America who have given to woman any political power. The Iroquois matrons had a representative in the public councils; they had a right to forbid a war, and a right to interpose in bringing about a peace. They possessed also considerable authority in family matters. Among the Nicaraguans—a people almost wholly monogamous—the husbands are said to have been so much under the control of their wives that they were compelled to do the housework while the women did the trading.

The mighty and benign power of love has probably played a larger part in the evolution of human society than the man of science commonly admits. It is comparatively easy to estimate the external forces of progress, and for this reason these forces have been long and widely studied. The result is that their effects have often been greatly exaggerated, while the more subtle and profound advance achieved by the various forms of human love has been almost lost sight of.

The Taboos which the Savage thinks are his Protection against Women

Unfortunately, scarcely any modern savage feels the highest passion of love. Superstition and custom compel him to regard his women as dangerous vessels of all sorts of mysteriously evil influences. A great deal of his life is spent in observing taboos which he thinks protect him from the perils of intercourse with the sex that he regards as weaker and yet more fearful than his own.

In many cases a marriage between savages is a kind of divorce. For instance, all the male Fijians, married and unmarried, sleep at the club-houses, of which there are generally two in each village. In New Caledonia the wife lives and sleeps by herself in a shed near the house, and so do the women in New Guinea. The Nubians have two dwelling-houses, one for the males, the other for the females; and there are Red Indian tribes with the same arrangement. The Bedouin tent is divided into two compartments for the men and women; no Hindoo woman must enter the men's apartments; and in Korea there is little intercourse between husband and wife. If a Hindoo wife were to touch the food her husband was about to eat, it would be rendered unfit for his use. The same superstition obtains in Egypt, in various parts of Palestine, in Siam, China, among many Red Indian tribes, and African negroes. Among the Barea tribe in East Africa the fear exists that if husband and wife sleep together the breath of the wife will steal away the husband's strength. This fear of effeminacy, in its literal sense, is at the bottom of these extraordinary taboos.

The Relations of the Husbands to their Wives among Lower Savage Races

It is not extravagant to say that the almost universal superstitious fear of women in primitive times is the chief cause of the degradation of the wife, and the long lack of progress in all marriage relations.

For this reason we are not inclined to agree with the numerous writers who consider that the degradation of woman began when marriage-by-purchase was evolved. It is true that woman thereby became a chattel, but the mere fact that she became valuable strengthened the marriage bond. When a wife costs many bullocks, or has to be earned by serving her father for two or three years, the ordinary man cannot afford to get a new wife on every occasion when his fancy changes.

Among nearly all the lower savages who are nominally married to a single wife whom they obtain with little trouble, the duration of the marriage is often very short. The Andaman Islanders, the Veddahs of Ceylon, and certain tribes in New Guinea and the Indian Archipelago are the only people in the lowest stages of culture who are known to be faithful all their lives to a single wife. The Indians of North America, for instance, dissolve their unions as readily as they enter into them; and long before George Meredith proposed one-year

marriages, the Creek Indians of North America had reduced the idea to a general custom. Among the savages in the interior of the Malay Peninsula it is not uncommon to meet persons who have been married forty or fifty times. The natives of Tasmania seem to have been as bad; and so were the Madagascans until they became converted to Christianity.

To put it shortly, among savage races, especially where women are obtained easily and single marriages are common, a man may divorce his wife whenever he likes. As Dr. Edward Westermarck points out, there is often a show of reason for the extraordinary fickleness of the lower savage. The savage woman very quickly loses her good looks; the hardships of a wandering life, the fight against famine, and the bearing of children rapidly make her an old, wrinkled woman. Often when a savage woman has reached her twentieth year the flower of her life is gone. About the same time she may begin to lose her motherly qualities. Bushmen women become sterile a few years after reaching maturity. Among the Fulah, of the Sudan, it is rare for a woman older than twenty to become a mother; and in Unyoro, one of the provinces of British East Africa, Emin Pasha never saw a woman over twenty-five with a baby.

Savage Marriages and the Effects of War on the Marriage System

These facts have a bearing, not only on the short duration of savage marriages, but on the problem of the almost general inclination to polygamy among the lower races. Many writers attribute rather too much to warfare in shaping the forms of marriage. It may be that the continual wars between the North American Indians kept down the numbers of men, and left many women the alternative of remaining unmarried or becoming the second wife of some warrior. But in Australia, where there are more male savages than females, the old men of the tribe keep so many young wives each that the young men have sometimes to wait until their thirtieth year before they are able to get married.

It is not in war and in other external conditions that the original source of man's sins against love lies. Pride of life and other things led him astray. He had the true light within him. The primitive Veddahs of Ceylon prove that; for they, at least, kept the flame of love pure and bright in their hearts, while they crouched in naked misery in their forests. Where all over the earth man rose to power and wealth, he degraded himself into a polygamous animal when he had the opportunity. Even the ancient Teutons—the ancestors of many of us—whose noble virtues Tacitus greatly commended to the decadent Romans, took several wives when rank and wealth enabled them; and so did the Scandinavians.

Yet, to the peoples of Northern Europe and their offshoots, the Dorian Greeks, the Romans, and the later nations that swept southward from forest and fiord, we must allow the high honour of evolving the modern lasting marriage of love between a single man and a single wife.

The Improved Condition of Wives who are Married by Purchase

They began, like many other races, with marriage by purchase. This form still obtains among many savage peoples, and it is seen in its full efficacy among tribes and nations in the agricultural stage of culture. The women do most of the work of farming, and they are therefore as valuable to their fathers as they are to their husbands. The practice of serving for wives obtains among rude savages, such as the Bushmen and the Fuegians, who possess little or no property. In this case the bridegroom helps the father of the bride in fishing and hunting.

It is worthy of remark that the men of both these very low races are distinguished by their love for their wives, and their family ties are very strong. These facts surely go to show that when women in savage or barbaric societies have to be purchased by labour or goods, their position is generally improved. They become too expensive and also too useful to be changed for a whim. Young Zulus who are without cattle have to wait many years before marrying. So in the New Britain group of islands, the price of a bride is often so high that the intending husband is middle-aged by the time he gets a wife.

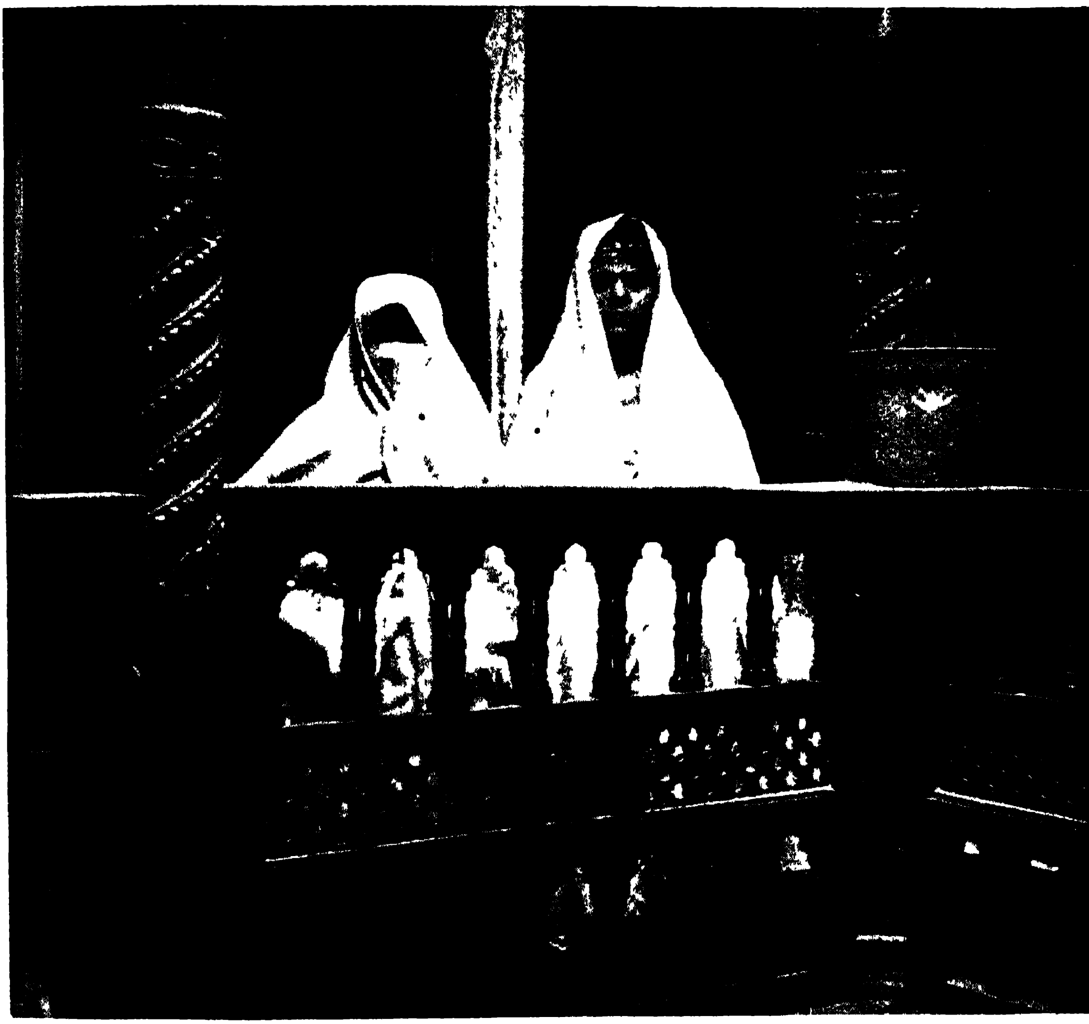
The Marriage-by-Capture Romance Built up on a Slender Foundation

This state of things leads naturally to the very curious variation of marriage on credit. When marriages of this sort take place the wife and her children cannot, as a rule, leave the parental home until all the instalments are paid. In Unyoro, to quote Emin Pasha again, if a poor man is unable to pay the cattle for his bride, he may hand them over slowly, one by one; the children born in the meantime belong to the wife's father, and each child must be redeemed by a cow.

It has often been suggested that marriage by purchase grew out of marriage by capture.

This view has an engaging simplicity and reasonableness, but savage customs are very complex, especially in regard to the union of the sexes; and, besides, it has never been proved that marriage by capture was ever a general practice. Few theories of primitive society have had such a vogue as that of marriage by capture, and few have been built on such slender foundations. The tinge of romance about it has, no doubt, had something to do with its popularity. But, as Mr. Ernest Crawley has now clearly shown, the widespread wedding ceremonies which have been mistaken for vestiges of a system of forcible abduction are only designed to bring out the ordinary, delightful fact that the bride is shy, and that her mother is loth to part with such a treasure of a daughter. Of course, there have been many elopements, and women have been carried away, over the bodies of their fathers and brothers, but these were accidents, and they did not affect the evolution of the institution of marriage.

Marriage by purchase is in its origin very obscure. The obscurity arises from the fact that the bride-price seems to have been customary long before the idea of buying and selling became connected with marrying and giving in marriage. So we get back to the dim region of primitive superstition. Now, gifts among savages are connected with savage ideas about magic. By giving anything belonging to you, you put yourself in the power of the person to whom you give it; for if he is evil-intentioned he may be able to cast a dreadful spell upon you by charming something that belonged to you. A gift, therefore, becomes the sincerest evidence of friendship.



THE MYSTERY SURROUNDING WOMEN AMONG ORIENTAL RACES—TWO WOMEN OF ALGIERS

The principle involved is personal and religious; it is a pledge rather than a price.

RUTH
whose marriage to Boaz is one of the Bible evidences of an interesting Jewish marriage custom by which property descended to women

Bride-gifts thus had originally a religious importance. But as the commercial instincts of the parents ripen, and daughters are found to have their price, the old idea fades into the light of common day, and marriage becomes partly a business transaction. But even among peoples where marriage by purchase obtains in its grossest form, the bride does not always lose all her rights in her bride-gifts. Marriage among the Kaffirs, for instance, is not a matter of mere barter. The cattle paid for the bride are divided among the male relations, but they hold them partly in trust for the wife and her children. For, if she is left a widow, she can demand assistance from everybody who has had a share in her dowry. Moreover, the father provides a marriage ox, which is a purely religious gift. It is known as "the ox of the bride," and it is eaten at the marriage feast. This ox stands for the value of the girl; it is also a pledge to the bride and bridegroom that when the father dies his spirit will not haunt their home, and it is, besides, a superstitious token that the marriage will be blessed by many children.

Marriage by purchase has an especial interest for us. Our old laws speak bluntly of "buying a maid"; and in Germany, throughout the Middle Ages, "buying a wife" was the common phrase for marriage. So in our marriage customs we are not very far removed from the savage Kaffir. Readers of Mr. Thomas Hardy's "Mayor of Casterbridge" will remember that some of our old-fashioned peasants are still inclined to think that they can put a halter round their wife and drag her to the market-place and

sell her to any bidder. The thing has actually been done in modern times, and many Frenchmen fancy it is still an ordinary English custom. Marriage by purchase flourished in the days of King Alfred, and Canute found it necessary to make a law forbidding the guardians of a girl from selling her in marriage for money against her will. But perhaps this was a recrudescence of barbarism due to the Danish invasion. For in spite of the commercial appearance of the Teutonic marriage the position of a married woman was a fairly happy one. For many years the old harsh forms endured but the spirit of the ceremonies seems to have changed for the better long before the spread of Christianity. At first a part of the purchase money was given to the bride and then the whole of it was bestowed upon her as a dowry.

No doubt the forces behind the happy evolution of marriage by dower out of marriage by purchase were of a moral and spiritual kind. Marriage by purchase had fulfilled its object in making the union of the sexes stable and lasting and out of the stability and permanence grew a stronger and purer feeling of love between the man and the woman which helped to give the woman more importance in the national life. Marriage by dower developed in turn owing to the fact that it put still greater difficulties in the way of a husband who wanted a divorce. Among the Teutons of early times the bride-price which was handed over to the woman as her marriage portion became her exclusive property, of which the husband could not dispose. And in addition to this wealth, which generally consisted of cattle,

RACHEL

for whom Jacob worked fourteen years, thus affording a Bible example of marriage by purchase. This picture is the copyright of the Berlin Photographic Company

THE WOMEN INVESTED WITH DECISIVE POWER IN THE DAYS OF ANCIENT ROME

A notable example of the mystery which still environs women in Oriental countries is the institution of the Vestal Virgins, the maidens of ancient Rome who guarded the temple of Vesta, the goddess of home life. They lived in a house in the Sacred Way of the Forum; and during the thirty years in which they were vowed to chastity they were invested with extraordinary powers, having sometimes a decisive voice in life and death The Virgins are here shown at one of their ceremonies.

she received from her parents an endowment—like the modern French *dot*—which was a sort of compensation for her inheritance, or an advance on it. This was also her private property, in that her husband had to return it to her if the marriage was ever dissolved. Thus an ordinary man who put away his wife lost a great deal of his property; and he had, besides, as in the old days of marriage by purchase, to provide another bride-price if he wanted to marry another woman.

For some hundreds of years after Christ marriage remained a civil contract, in which no priest took any part. It was a private family matter, like the selling of a house. In England it consisted of two separate treaties—the wedding or the betrothal, in which a ring or a penny was presented to the bride as earnest-money; and the real marriage, or giving of the woman, when the cattle were handed over, and the girl was made a wife. The modern engagement-ring now represents the old earnest-money given to the intended bride; and the best-man of the bridegroom is the sole representative of the friends who used to stand surety at the betrothal for the payment of the bride-price.

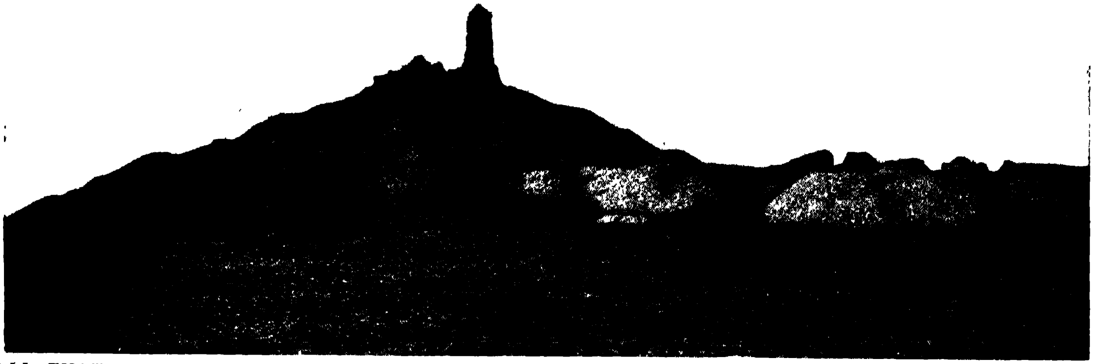
The modern civil marriage is generally regarded as an extraordinary innovation. But it is not so in fact. It was not until the tenth century, in England, at least, that a marriage became an ecclesiastical institution, and a priest took any part in the marriage service. Even then the marriage rites were only performed before the door of a church, where the priest closed the ceremony with a blessing. Throughout the Middle Ages the principal act of the marriage celebration—that is to say, the consent of the parties—was conducted at the porch of the church in England, France, and Germany. And marriages continued to be celebrated at the church door until the sixteenth century, when the liturgies of Edward VI. and Elizabeth first required the ceremony to be performed in the sacred building.

THE TOTEM POLE OF A PRIMITIVE RACE
The totem is an animal held sacred by certain primitive races as having a magic power of protection; and totem poles like this are set up in villages.

As Dr. Westermarck, perhaps the best authority on the subject, says: "The history of human marriage is the history of a relation in which women have been gradually triumphing over the passions, the prejudices, and the selfish interests of men." The tale of the evolution of marriage is really the story of the growth in strength, purity, and constancy of the divine spirit of love. Some persons at the present day seem inclined to doubt whether we have reached the highest stage in the development of the institutions which regulate the union of the sexes. Well, as a modern novelist remarked, civilised man has passed Seraglio Point, but he has not yet rounded Cape Turk. His natural instinct, that is, still breaks through civilisation. Our hearts need to be cleansed, and our wandering imaginations purified, before we have completely reduced to practice the high idea of monogamy. We have still much to learn from the Veddahs of Ceylon, who are said to be the most primitive people in the world, every man of whom remains faithful until death to a single wife.

On the other hand, the notion of evolution and progress can be pushed too far. There is no progress in marriage beyond monogamy. Everything put forward as a pretended substitute by writers of the revolutionary school is a degradation from a standard of perfection which we have yet fully to attain. Savage and barbarous races in various parts of the world are carrying out all the so-called "advanced ideas" on marriage found in our recent literature of rebellion, and in every case it is clear that these ideas are a degradation. Marriage for life between one man and one woman is a sacred institution; it is built out of the tears and blood of many martyrs, out of the sufferings of the countless women who existed in the long ages before it was established.

LO! ALL OUR POMP OF YESTERDAY



ALL THAT IS LEFT OF ONE OF THE GREATEST CITIES OF BABYLON AT THE HEIGHT OF ITS POWER

WHERE CÆSAR WALKED IN ROME--THE FORUM AS A RUBBISH HEAP 1500 YEARS AFTER THE EMPIRE

THE SITE OF THE GREAT SEAPORT OF CARTHAGE

"Far-called, our navies melt away; On dune and headland sinks the fire: Lo! All our pomp of yesterday—Is one with Nineveh and Tyre."—Rudyard Kipling

NATIONS OF THE FUTURE

The Underlying Forces which may Change the Future of the World and Upset the Balance of Power

ROOM FOR THE WORLD TO LIVE

GREAT BRITAIN, the United States, and Germany — Anglo-Saxons so-called, and Teutons—these and some others we reckon the leading nations of the world. Australia is an Anglo-Saxon continent; there are Spaniards and Portuguese in South America; there is a welter of brown and yellow in Asia, much despised as "natives" and "yellow monkeys" by the few Europeans in the continent; and the white man invades Africa, where he is distressed to discover a "black peril."

Such, apparent and untested, is the balance of power in the human family at the present time. Was it always thus? Will it be always thus? And, if not, what are the forces which will change it, whither do they tend, and what do they portend?

Certainly it was not always thus. There was a time when, throughout the known world, to say "I am a Roman citizen" was to ensure safety and homage. "I am an Italian" does not sound the same in Soho or New York to-day. There was a time when Spain well-nigh mastered the world, and could do almost as she would in the Netherlands; and only the other day the so-called Caucasian race, as represented by Russia, seemed to have the yellow world at her feet. More remotely there were periods of Greek and Egyptian dominance; a period when Minos of Crete swayed a sea-empire which all men feared; and an epoch, said to have endured for four thousand years, when Babylon and the Babylonians were the dominant people of the earth.

Why are things otherwise now? Has the rain ceased to fall, the rivers to flow, the soil to bear its harvest, the sea and the mountains to protect, where formerly these nations were so happy and so strong? And if the external conditions persist, in all essentials, so that geography and the face of the earth are not responsible, where are we to seek for the cause of these tremendous changes? Cause there must be; and the doings which destroyed Rome and Babylon, the factors of this universal and recurrent tragedy called Decadence, must doubtless be essentially the same from age to age, whether in Asia or in Europe, or wherever else nations are born and grow and flourish, and have no more external foes to fear, and then fall, struck at the vitals by some secret malady which no battalions could disperse, and no physicians diagnose.

It might be that races differ widely in their natural powers, so that some are destined ever, and some never, to be slaves. It might be that yellow and white have only to meet for the yellow to succumb—as we should expect; or the white to succumb—as in point of fact happened. But history does not bear this out. On the contrary, races are sometimes dominant, sometimes enslaved; and they are never so much in peril as when all peril seems past. In the history of nations, as of individuals, the paradox is incessantly illustrated that nothing fails like success.

Thus, wherever we can adequately trace the history of any part of the earth's surface, we find that it has repeatedly and successively been overrun and occupied by conquerors of this, that, and the other race, who have managed to make a place for themselves, to oust established possessors, and yet could not maintain what they could win. No measure of success, no "far-flung battle-line," no bottomless coffers, no public buildings, no annual tribute of money or men or maidens, no glories of literature or art, no physical culture, no higher education of women, have availed in the long run to avert the fate of all our imperial predecessors from Babylon to Spain.

Man alone, of all living beings, constantly increases in numbers. In exceptional

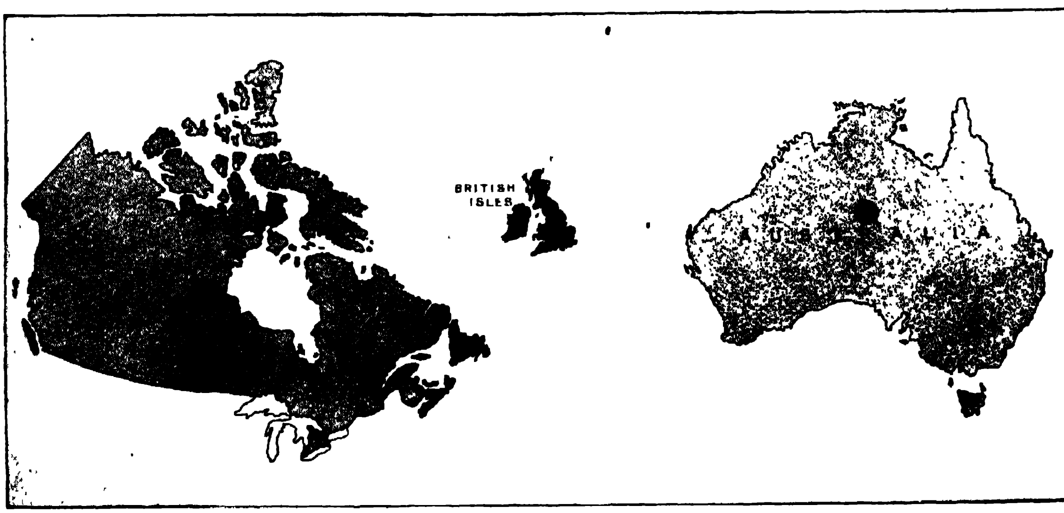
in most notable accord with the opinion of humanitarianism, and knocks the bottom out of the practice of the "practical man."

Here, then, we shall ignore the Tropics, as probably furnishing a special case, due to the local conditions; and, having noted in passing that history records no tropical civilisation, whatever that notable fact may mean, we may ask ourselves what will be the consequences, in the near future, of the law of population-pressure, acting in the temperate zones, if present rates of increase persist. To this question, which is probably of unparalleled moment, certain answers can be returned.

Thus, it is a necessary consequence of the law of population-pressure that if Germany continues to add some eight hundred thousand units or so to her population every year, and France adds comparatively none, France must therefore inevitably become weaker than Germany, and undergo Teutonisation. The two lost provinces merely presage the future. War there may not, need not, should not be, but through what the physicist would call the "semi-permeable membrane" of the Franco-German frontier, French and German units must pour in either direction in proportion to the pressure behind them; and this German immigration into France, far exceeding the contrary process, and at this hour a major fact of European politics, must persist until equilibrium is attained. Intermarriage or racial mixture on a wide scale there will doubtless be, as there has always been when this law has asserted itself, gradually or with military violence, in the past, but the ultimate result will be the expansion of the German people into France. That fertile land could now maintain three times its present population, to say nothing of the consequences of future developments in agricultural science.

Much more striking is another contemporary instance, which presages tragedy in the not distant future unless wiser counsels prevail, as they have never yet prevailed in uneducated democracy. We own, but we do not occupy, an almost uninhabited continent, called Australia, of which ex-President Roosevelt has lately declared, very greatly under-estimating the truth, that it would support ten times its present population. Some day it will support nearer a hundred times its present population. Of both New Zealand and Australia it is true that the universal laws of life have undergone modification by the action of a new factor—voluntary control of the birth-rate. These populations, with every advantage, with no traditions or vested interests to handicap them, protected from aggression by their imperial connection, with a negligible native population to encounter, deliberately decline to increase. They are the latest illustration of the truth that nothing fails like success.

In order to safeguard against that struggle for existence which, throughout the living world, follows from the pressure of population upon food-supply, the Australian democracy has not encouraged immigration,



THE VAST SPACES AWAITING FUTURE POPULATIONS, SHOWING THEIR SCANT POPULATIONS NOW

If Canada and Australia were peopled to the same extent, compared with their size, as the British Isles, the populations would fill an area equal to the small circles on these maps, leaving the rest uninhabited; yet, so vast are these territories, and so small are these populations, that, while Great Britain has 373 persons to a square mile, Canada has only two and Australia only one for each mile.

and absolutely bars the incursion of the Japanese. We have thus a case parallel to that of the gases already considered. The membrane between the regions of high and low pressure has been made impermeable. The low pressure on one side of it remains low, and the high pressure on the other side of it steadily rises. Will the barrier of immigration laws last for ever ?

All history and probability must be falsified if this can be so. Whether by the removal of the barrier or the making of apertures therein, or by that form of human explosion which we call war, it is necessarily certain, *if present tendencies persist*, that Australia must ultimately become the home of a Japanese population. Let us observe the facts of rising pressure on one side of the barrier, and compare them with the spectacle of stagnation on the other, while men boast their patriotism in public, and privately say: " After us, the deluge."

Statistics regarding Japan must be accepted cautiously unless they be of very recent date. It appears, however, that in a period of approximately a quarter of a century the birth-rate in Japan has very nearly doubled—rising from 17·1 per 1000 to 31. Until very lately the present writer has doubted these figures, since they appear so exceedingly improbable, and because of the extraordinary contrast which they present to the rest of the civilised world. But there can no longer be any doubt about them, or about their meaning. Japan, the imitator, having bodily annexed our civilisation, appears to have rejected its most notable and ominous consequence. Further inquiry shows that the striking rise in the birth-rate of Japan has followed on the Russo-Japanese War. The drain upon the manhood of Japan in that campaign was enormous, necessarily bearing a far higher ratio to the total population than in the case of a huge population like Russia's. We are definitely informed that not only has the birth-rate subsequently risen in this unique fashion, but its rise is deliberately compensatory for the losses of the war. The mothers of Japan, in

THE ASTONISHING RISE OF NEW CITIES—WINNIPEG FORTY YEARS AGO AND NOW

short, are presenting their Fatherland with new citizens to take the place of those whose lives were laid down in the war. Thus is Bushido, the patriotism of the Japanese, showing itself in the most remarkable manifestation of patriotism in recorded history—more provident, more responsible, farther sighted, more fundamental than anything which can be brought into comparison with it.

In China, hitherto, the growth of the population has been largely controlled by deliberate infanticide, and recent evidence suggests that the population of China has been considerably over-estimated. Nevertheless, the Mongolian population of the world must amount to more than one fourth of the whole, and the anthropologists report that the Mongolian brain is, on the average, heavier, and not of lower organisation, than that of the white man or so-called Caucasian. There is a yellow peril, therefore, for the final reason that the yellow people of the earth are increasing at a much faster rate than the white—or the brown or black, for the matter of that.

A MAN TO RECKON WITH IN THE FUTURE

Japan's rapid rise, and her dramatic bid for power in the modern world, are doubly significant when we remember the growth in her population. The birth-rate in Japan has nearly doubled since the war with Russia, which gave Japan her opportunity, but drained tl on of great numbers of men.

Thus, to consider for the moment Japan alone, the pressure in that archipelago persistently and rapidly rises; while the Australian birth-rate falls, and the population is barely more than maintained by the ridiculously scanty flow of immigrants, mostly males, received from this country, who cannot, by themselves, "found an imperial race," or any other kind of race. It necessarily follows, therefore, that, failing gigantic changes in national practice and temper, of which there is no indication nor likelihood, the yellow race must one day teem into Australia, in one way or in another, and doubtless proceed to make history there on a substantial scale.

Moreover, it is true, of course, that the Chinese, whose name is legion, are a superior people to the Japanese, of whom they are the tutors. The Chinese system of ethics, whether intentionally or otherwise, is intensely eugenic, in that it requires a man to have offspring to worship him and guard his name. The supreme importance attached to the family, to parents and to offspring, by the Confucian system, is, in the judgment of some modern observers who have firm hold of the fundamentals of national existence, the chief reason for the persistence of the Chinese, as for that of the Jews, who have always reckoned that man happy whose quiver is full. But if a people such as the Chinese, already the most numerous in the world, capable of extreme physical endurance, sober, non-alcoholic—thus avoiding the chief active agent of racial decay—incredibly industrious, content with and able to maintain life upon the simplest, cheapest, and most meagre diet, and endowed with brains at least as good as any that men have—if such a people multiply more rapidly than their neighbours, there is only one possible issue. These people must become, if not the masters of the world, as the Romans once were, yet at least the first among its masters.

A conclusion like this is intensely repugnant to the instincts of probably ninety-nine non-Mongolian readers out of a hundred.

That, however, does not make it incredible, and is totally beside the mark of science, which is concerned with no one's likes or dislikes, except in so far as these are themselves facts for its record and interpretation. The conclusion now before us follows irresistibly from the premises. The premises may not be sound, or may not remain sound. The present population of Australasia may start to work more than an hour or two in the day, or a day or two in the week. The leaders of that most significant democracy may change their views, or it may even some day produce a Man. The birth-rate may rise rapidly, while the admirable care of infants—the infant mortality in New Zealand is the lowest in the Empire—may persist. White immigration, not less of girls than of boys, may be henceforth encouraged as never before. But these things are immensely improbable. They could flow only from moral forces of high intensity, such as are not easily generated, and which nothing at this hour heralds.

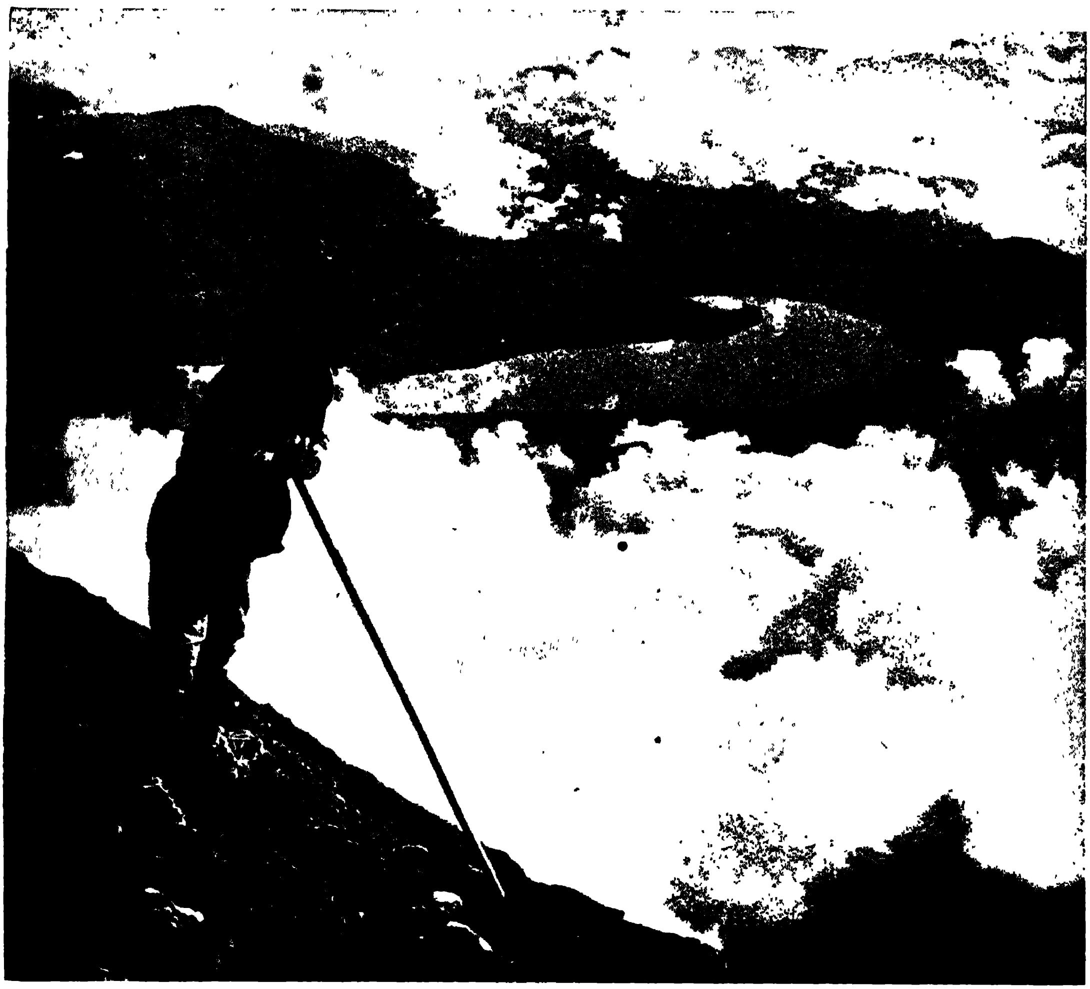
THE COMING-UP OF YOUNG CHINA

Chinese children learning under Western guidance. A scene in a day-school at Canton for girls organised by Christian missions

Yet we cannot refrain here from expressing the earnest hope that Australia will at least encourage, by every means in its power, and on a scale hitherto unimagined, the immigration of its cousins, and, above all, of healthy young women, who are at all times the chief hope, and should at all times be the chief concern, of any nation.

The extraordinary welter of races in the United States, and the singular disproportion between the birth-rates of its various constituents, cannot now be considered, though at present it appears unlikely that North America will always be an Anglo-Saxon continent, and though we remember what invaders the western border of the continent now fears. But the case of South Africa must be referred to more especially, since this completes the tale of the continents in our brief survey. The myth called military conquest, when it is not backed by the pressure of population, is scarcely better illustrated by the present state of France, which all but "conquered" Europe a century ago, than by the present and imminent state of South Africa The British have lately conquered South Africa, and imposed themselves upon it; but there is only one lasting way of conquering any country, and that is with women as well as men, and with babies thereafter. In South Africa now the Briton is to be found, usually doing well for himself as an individual. He comes and he goes, as his regiments came and went. He may make the most money, he may be mainly responsible, even, for material progress and prosperity on those visible surfaces which sight can see but which insight sees through. His imposing mansions do not impose upon the Eugenist, who sees through their walls to empty nurseries. The question for the future of the South African nation, which must necessarily be one of the great nations of the future, is the proportion between the British, Dutch, and native birth-rates. The Dutchman lives and multiplies there; and, unless the British multiply, too, the future belongs securely to the Dutch, the Boer War, or a hundred such wars, notwithstanding.

But, lest we be accused of lacking a sense of proportion, let it be said that the origin and the density and the distribution of populations are not everything, even though we believe them to be fundamental. There is the social heritage, no less than the



"THE LITTLE MAN ON TOP OF THE WORLD"—A JAPANESE TRAVELLER ABOVE THE CLOUDS

The enormous increase in the population of the yellow races, coupled with the fact of the emergence of Japan from despotism into the rank of a powerful modern nation, makes up a factor in world-development which may have incalculable effect.

physical, the heritage of literature and tradition, and custom and spirit, which man alone possesses, and which suffices to make his life unique. There is very little Greek blood in modern Europe, and it may be that even much of what there is has degenerated. But it has been said, no doubt in picturesque and therefore excusable exaggeration, that nothing moves in the modern world which is not Greek in origin, nothing which was not born and set going in the little city-state called Athens. No less truly may it be said that the greater part of modern history, and the greater part of the moral and religious forces which have made and still make it, are Syrian in origin, derived from a small and despised race, whence came the Christian Church.

If such arguments be sound, if words spoken in the market-place or on the Mount two thousand years ago do now move and mould modern men and women, determining their deeds, and therefore their destiny and the world's, it follows that the population question and physical parenthood, transcendent though its ultimate importance must be, are not all. There is spiritual creation and transmission also—of things which, being not seen, may be eternal. A Socrates may leave no children, nor a Galton nor a Lister; and a Shakespeare's may be negligible. But there are ideas and ideals, for which men or nations stand, which are imperishable while man is man at all. England may some day be the home of seaweed and deep-sea fishes, while argosies of other peoples sail over her watery tomb, but her Kelvin's compass will guide them, her Shakespeare thrill, her Lister heal, her Newton teach, and her Nightingale inspire.

THE ETERNAL MILLS OF GOD

The Mighty Energy that Drives the World-Machine, and the Fear that the World will Run Down

THE UNIVERSE THAT IS FOR EVER YOUNG

The universe is often looked upon as a machine, a great piece of construction which was made in order to "go," and goes accordingly. There is no doubt, indeed, that the universe is a machine, though it is also immeasurably more; and evidently the machine goes, for we see its motion and action on every hand. Indeed, they are displayed in the hand that writes these words, and the rotation of the eyeballs which scan them.

The machine has therefore some kind of power or motive force within it; and we are naturally impelled to ask whether this power was put into it, in the beginning, and whether it is now, however slowly, in process of running down. This idea corresponds to one of the oldest and commonest notions in the world; and we shall find that it took a kind of scientific form, in the nineteenth century, as the doctrine of the "dissipation of energy," which was introduced by Lord Kelvin, and which only within the last few years—since his death, indeed—has begun to lose its authority. Kelvin thought that the universe must run down and come to a dead level of heat and power, so that neither motion nor activity nor change could be found in it again. It would be a dead universe, which had run its allotted span of life, and was now no more than a cold and changeless corpse.

This view of things involves an end to the universe—when its power has given out; and a beginning—when its power was put into it. Indeed, it is simply the modern, or perhaps now we should say the nineteenth century, version of an older idea which Carlyle had described with magnificent scorn. This is the idea of the universe as a clock, made and wound once upon a time by the Almighty Clockmaker, who now rests from His labour, and, from far away, watches the clock go, until at last it has exhausted the power originally put into it, and the end of all things is come. Carlyle, we remember, declares his preference for the idea of the universe not as a dead machine, with its maker outside it, but as a living tree, nourished from age to age with the forces of life and action, ever replenished from the inexhaustible stores of Deity. It should evidently be worth our while to study the details of motion and of force, which will enable us to determine which of these two ideas more nearly expresses the truth. But it will be strange if the verdict of the astronomer, and the physicist, and the chemist does not favour the view which commends itself to philosophy—the view that the universe, in so far as it is a machine at all, is a Perpetual Motion machine, whose power to go is the very essence of itself, which never needed winding up, and will never run down.

In this great inquiry, which matters so much not only for science but also for philosophy and religion, the idea of energy is our guide; and here we owe a great debt to the scientific work of Kelvin, however little we may value the strange theory which he caused the scientific world to accept for the better part of half a century.

The first universal fact about energy is its incessant transformation. The whole of the activities of the universe, its changes of form and motion, the production of light by a star or a candle or a glow-worm, or an electric current in a wire—all these depend upon the transformation of energy. All forms of energy are forms of one and the same thing, and they can be transformed into one another—light into heat, heat into motion, motion into light, chemical energy into motion, as when a bullet is fired—and so forth. In this process the form of the energy is changed, but its substance remains.

On inquiry, we find not only that it is really one thing which is capable of so many transformations, but also that it remains constant in quantity, however much it be changed. The householder expects so much electric light to be derived from so many units of electrical energy; and if his lamps have been burning for a certain number of hours each quarter, he expects the bill to be for the same amount.

How the Motor-Car Turns the Energy of a Gallon of Petrol into 20 Miles of Motion

So much electrical energy yields so much light energy. It is true that the energy the householder pays for is partly turned into heat, which he does not want, and partly into light, which he does want; and that he gets thus different results with different types of lamps. But the law of the equivalence of energy is observed nevertheless; and the only difference is that the more economical lamp turns a higher percentage of the electrical energy into light energy, and a smaller percentage into heat energy.

Again, the motorist gets his pleasure by turning the chemical energy of petrol into the energy of motion of his motor-car. Though he may know nothing of the law of the conservation of energy, which we are about to consider, he does at least know that if his petrol has run out his car will not run on. No petrol, no motion. And he also knows something of the law of the equivalence of energy, for he reckons that one gallon of petrol is equivalent to, say, twenty miles of motion, or ten miles of motion if the car's weight be doubled. If this equivalence be not observed he knows that something is wrong, and examines the engine, adjusts the bearings of the wheels, re-inflates his tyres, or what not. In so doing he is a man of science, recognising and assuming the truth of the law of the equivalence of energy.

The Potential Energy Waiting to Spring and the Kinetic Energy that we Can See

Every act and fact of the world's doings is an illustration of this universal law; and we should look round for ourselves until we realise how universal it is. Particularly must we observe that this transformation and equivalence of energy is true in any direction. Heat, as in a steam engine, will produce motion, but we have only to rub our hands quickly and firmly on a carpet to realise that motion can be turned into heat; or to look at the shooting stars that flash through the atmosphere, and consider that these are dark bodies, flying through space, which suddenly encounter the resistance of our air, and lose much of their motion, which is transformed into the heat and light that we see them by.

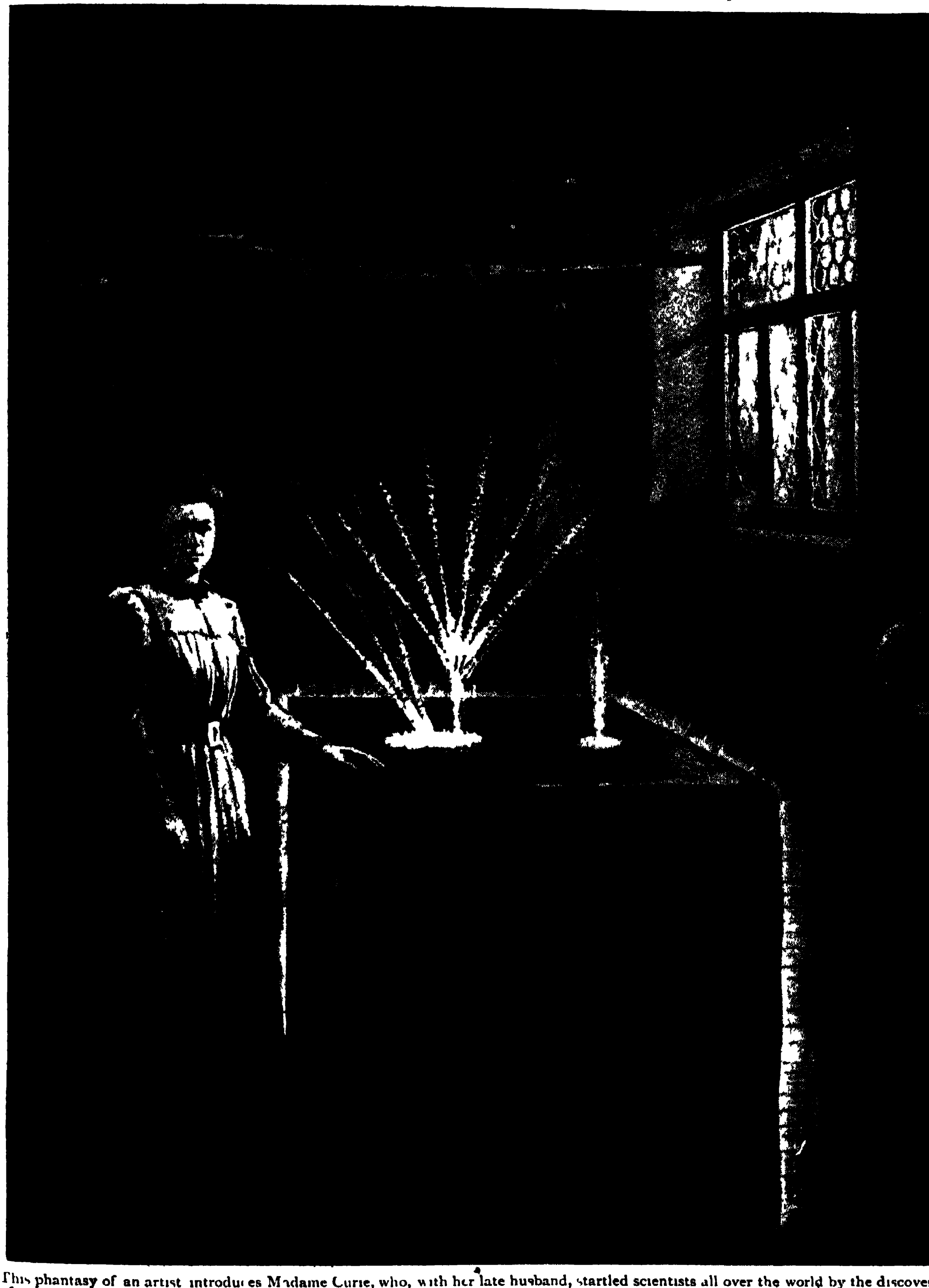
In all these transformations we can recognise two great types of energy, which are to be observed—as all these laws may be observed—equally in the stars or in the behaviour of our own bodies, or in the growth of a seed. Energy may either be latent, waiting to spring, coiled up, but not let go, in which case we call it potential energy; or it may be actual, active, visible, moving, in which case we call it energy of motion, or kinetic energy—from the Greek word for motion.

Having got so far, men made a great discovery which alone was wanting f r a greater discovery still. They proved that heat is "a mode of motion," or kinetic energy; and that a given amount of heat is always equal to a given amount of "work"—that is to say, such work as lifting a given weight to a given height. So much heat will do so much lifting, and the energy produced by the lifting will reproduce just the same quantity of heat.

The Potential Energy of a Five-Pound Note that Turns into Very Rapid Motion

Heat, therefore, which is almost always produced whenever energy is transformed —whether we want it or not—is a form of energy, and we cannot omit to reckon it in when we try to understand the laws of energy. The heat produced by an electric bulb or a candle may be a nuisance if we only want light; and the motorist is not at all pleas d at the fact that much of the energy which he has paid for in his petrol turns not into the motion he wants, but into the heat which he doesn't want, and which, indeed, often hampers his engine, so that he loses his motion. The man of science, however, is well pleased to study the production of heat in these cases, and to realise that the electricity, or the wax, or the petrol, means a store of energy which may be turned into light, or motion, or heat, or any combination of these; and that in each and every case the law of equivalence is observed. Just so is it observed when a piece of paper, a cheque or banknote—which has only potential energy, so to say—is turned into the energy of motion—only too rapid!—of, say, five pieces of gold, or a hundred of silver, or twelve hundred of "copper," or any combination of these, *provided that* they are equivalent to five pounds. Just so, also, the gold and silver and copper, or stamps or

MADAME CURIE, THE MODERN ALCHEMIST



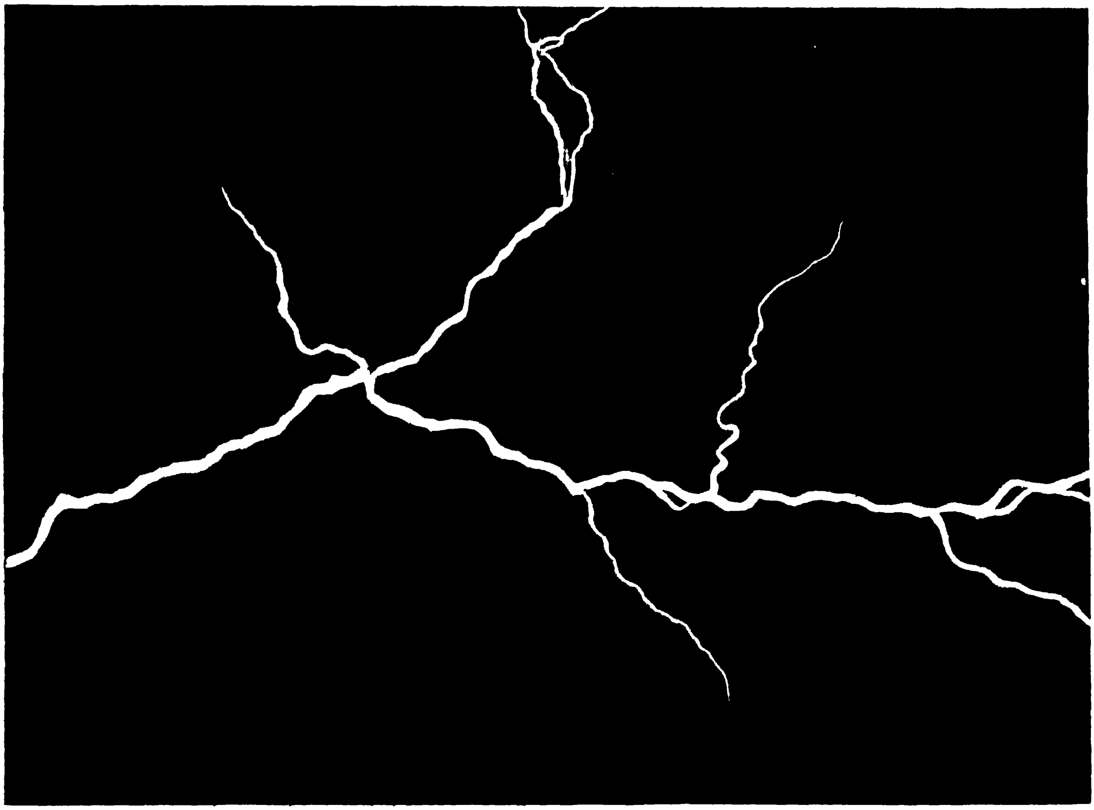
This phantasy of an artist introduces Madame Curie, who, with her late husband, startled scientists all over the world by the discovery of radium. The huge black block represents a mass of pitchblende, the material which gives out radium and polonium. Radium is represented by the large white patch on the left of the block, and polonium by the smaller patch on the right, and each of these substances gives off emanations of its own. On the right the polonium is seen giving off Alpha rays, and the radium on the left is giving off Alpha, Gamma, and Beta rays, as well as an emanation—shown rising up straight from the block—which changes into helium and ultimately into radium. The fact that pitchblende gives off energy in this way means nothing less than the breaking up of the atom, which was once considered the foundation stone of the universe.

what not, may be gathered together again, and transformed into the potential energy of another cheque equivalent to that for which they were drawn.

So much for the doctrines of the transformation and equivalence of energy. The terms may be a little unfamiliar, but the facts are really simple and reasonable ; and we are perfectly familiar with the principle of them in our daily lives whenever we buy anything and wait for the change, or in any process of exchange whatever.

And now we come to the great discovery. Suppose we cash our banknote and then decide to turn the cash back into a note again, and find that the cash is sixpence too little or too much. We know that something is wrong. We never believe that a sixpence disappeared by annihilation, nor that a sixpence doubled itself spontaneously. Either a sixpence has slipped through a hole in our pocket, or a sixpence was in the pocket to begin with. Some such explanation there must be. We decline to believe either that a sixpence became nothing or that nothing became sixpence.

If we agree so far, we are indeed prepared to agree with the law of the conservation of energy, which simply asserts about all energy, in all times and places, and through any kind and number of transformations, what we believe about the form of energy called money, in such a case as we have supposed. The law is not completely described by its name, which, indeed, applies to only half of it. The energy which makes and moulds and moves the universe is indestructible ; its quantity is never decreased. Nor can any more of it be made ; its quantity is never increased. That is the law of the conservation of energy, and its importance cannot be too highly rated.

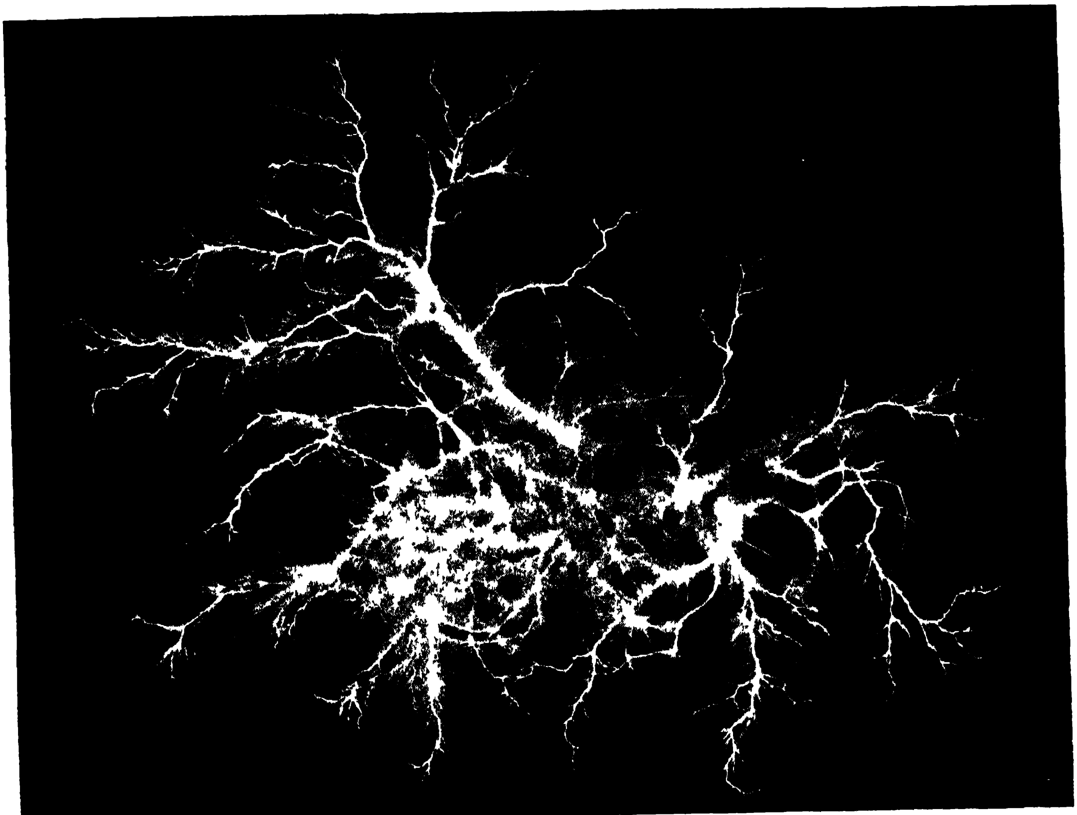


ELECTRICAL ENERGY IN THE SKIES—PHOTOGRAPH OF A FLASH OF LIGHTNING

All forms of energy are forms of one and the same thing, and can be transformed into one another light into heat, heat into motion, motion into light. This photograph shows electrical energy in the universe manifesting itself in the familiar form of lightning ; some of it turns into sound, but thunder cannot be photographed.

Before we really set ourselves to consider what it means, let us meet the supposed exception furnished within the last few years by the discovery of the unheard-of behaviour of radium. We must clearly realise that this is one of those scientific laws of which the whole essence is that there can be no exceptions to it. What are called " laws " in science are of many kinds, and the term is indeed a bad one. But

some are absolute generalisations, which either apply everywhere and always, or are untrue and apply not at all. The law of the conservation of energy is one of these. If anyone anywhere makes something out of nothing, or gets power without having spent power, which is indeed to *create* in the full sense of the word; or if anyone can destroy power so that it is really made into nothing, annihilated, then the law of the conservation of energy is untrue, and anything is possible. The rarest, smallest, briefest exception must therefore be fatal; Unwise commentators have therefore declared that this great law, the establishment of which was one of the most magnificent achievements of the nineteenth century, has been broken and falsified by the first discovery of the twentieth. No one of really scientific and impartial mind could believe such nonsense. The power of radium must come from somewhere, or a miracle is before us, and all the rules of thinking and arguing break down: "chaos is come again." Our business in such a case is to jump to no conclusions, least of all an



ELECTRICAL ENERGY ON THE EARTH—AN ELECTRIC SPARK MADE BY MAN

The picture facing this is a natural electric spark, which we call lightning a flash of natural electricity set aglow in the heavens. The picture on this page shows a flash of man-made lightning, being a photograph of an electric spark, such as occurs in a motor-car. Both these photographs show manifestations of the same form of energy.

and if it be fatal to a law supposed to be universal, this least and most local exception is of universal importance.

We commonly expect, as this law assures us must be the case, that we cannot get heat and light without using up energy of some kind—chemical energy, electrical energy, or what not. Radium, however, displays a form of action called radio-activity, which involves the production of heat and light among other things; and it does so for any length of time, as would appear, and without any energy being supplied to it.

unthinkable conclusion—as the creation of something out of nothing really is—but to examine the facts. That examination, as we already know, revealed that radium derives its energy from a mighty reservoir within its atoms; and, indeed, if the law of the conservation of energy had been in need of further proof, the recent work on radium would have supplied it abundantly.

One other point before we discuss the full meaning of the law of the conservation of energy. It is a point which helps us to understand the meaning of the law perhaps

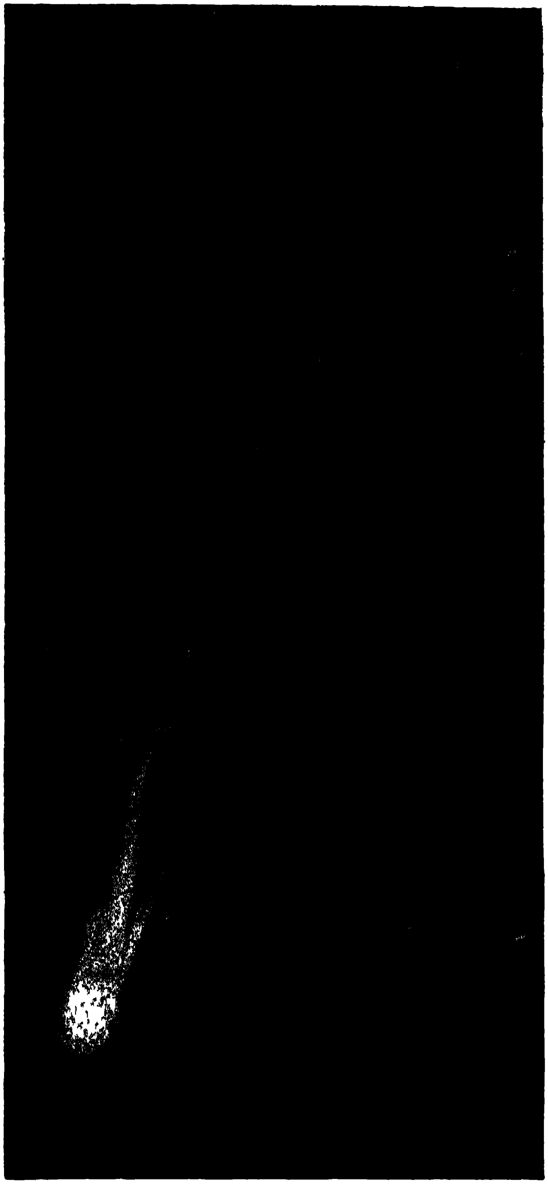
THE MOST TERRIBLE EXAMPLE OF CHEMICAL ENERGY THAT CAN BE SEEN IN THE WORLD

The first universal fact about energy is its incessant transformation, upon which the whole activities of the universe depend. All forms of energy—light, heat, motion—are different forms of the same thing. The firing of a big gun, shown in this photograph, is the most remarkable example that science has made possible of the transformation of matter into motion, brought about by the letting loose of the pent-up gases in gunpowder.

better than anything else can. We have called the universe a "perpetual motion machine." Certainly there is no other perpetual motion machine, in the ordinary sense of that phrase, and now we can realise why all the would-be inventors of such machines have failed.

They have tried to get something for nothing; cunningly to score off Nature, and cheat her into giving them five sovereigns and a sixpence for a five-pound note—or for nothing at all. They have tried to make a machine which would work without requiring power. Since work cannot be done but with power, this means that they have expected their machines to create power out of nothing. Several scores of years have passed since the Paris Academy of Sciences decided that it would no longer even look at inventors' specifications for such machines.

That decision was taken long before the law of the conservation of energy was established and proved. Those who had thought about the subject knew, from the very laws of thought, that these inventors and all future inventors of such machines must be deluded. We have only to grasp the real nature of the problem these inventors set themselves, the problem of absolute creation out of nothing, to know that they cannot succeed. You might as well try to invent a machine by which twice one could be made into three. The laws of reason, and the law of the impossibility of creation out of nothing, forbid.


A POWER WHICH RESISTS GRAVITATION
Under the influence of radiation-pressure acting upon itself, a comet's tail turns away from the sun. While the heavy head of the comet is drawn towards the sun, the radiation-pressure on the tail is stronger than the gravitational pull of the sun; and the tail of a comet, shown in this photograph, is one of the few things in the universe which appear to resist gravitation.

Herbert Spencer was therefore right in building his whole philosophy upon this great law of the conservation of energy, and declaring that it belo ged to the few absolutely certain truths, which we may know by the test that their opposite cannot really be conceived. We cannot really conceive creation or annihilation; and that is the best proof of the law which declares that they do not happen.

This brings us to the heart of the matter. Both creation and destruction are denied by this law. We simply misstate and misunderstand it if we do not realise that it contains both these denials, and that they are the two halves of one truth. The "perpetual motion" inventor fancies he can create power out of nothing; and he fails invariably. Many other people suppose that power can disappear, not merely in the sense of being no longer visible, but in the sense of being made into nothing; and their mistake is really the complementary one to that made by the would-be inventor.

We are to accept it as proved by all the evidence, and as a necessary law of rational thinking, that all the universe, devoting itself with all its powers to the making of just one more iota of power—just so much as would stir the least grain of dust—would fail; and also that if all the universe, except one iota of power, were to set upon that and seek to destroy it, the attempt would fail. That is what the conservation of energy means.

It follows from this that at every moment of our scientific study we must seek to account for all the power we witness, and all the forces at work. We may fail to do so, but we must never conclude that these powers did not come from somewhere, but rather that we must go on looking for their source. The powers of radium are the most striking and subtle case in point.

The Power that Slips from Our Grasp and Goes Out into the Universe

And further, whenever power seems to disappear, with nothing to show for it, we must be absolutely certain, appearances notwithstanding, that that power has gone somewhere. It may be lost to us, and too often, indeed, that is what has happened, but it is not lost to the universe. Our motor-engine may simply make itself hot, and refuse to go. We have lost the power, and cannot recover it, for the heat glides away into the air irrecoverably; but it is there, nevertheless, and the universe may have means of making it available again in its own good time.

This last illustration leads us to reconsider the remarkable and awe-inspiring doctrine advanced by Lord Kelvin, and called by him "the dissipation of energy." Kelvin had made useful additions to the work of the great German and French pioneers who established, with the aid of the Englishman James Prescott Joule, the law of the conservation of energy. He then set himself to study the tendencies, as we may call them, of energy in the course of its transformations, and he found that it always tends to escape from usefulness.

It tends to spend itself in the form of heat, which scatters its force on all sides, and can no longer be employed for purposes of work.

The Heat that Runs to Waste in All the Workshops of Man

This waste, in the form of heat, is the incessant problem of the engineer, and of those who provide for artificial lighting; and indeed even the eager controversialist is often prone to produce useless heat rather than the abundant light which the subject requires. In general, we may say that in all the transformations of energy a certain quantity of it is apt to leak away as heat.

The tendency of heat is to spread itself out, like water, until it finds its own level, where all things are at the same temperature. If the motorist could catch all the heat into which even the best engine must necessarily transform a fraction of the energy in his petrol, then there would be no waste. But he cannot. The heat escapes him, and is lost. If we do not grasp the great distinction between the annihilation of heat or any other form of energy, and its loss or waste, we need only compare it to the case of money turning into nothing in our pockets, or dribbling away through a hole. The first cannot and does not happen; the second may and does.

Now, said Kelvin, this process of the gradual leakage, waste, and loss of the available energy of the universe is always going on. So long as one thing is hotter than another, power is available, and work can be done, as in the case of the sun, which is hotter than the earth, and provides power for the earth. But in this very act, and in all other transformations of energy, the heat levels of the universe, so to say, tend to become the same; and when that happens they can no more be made to do anything than the water which has fallen into the pond below can drive the mill-wheel above it. All energy runs to heat, and all heat runs to one level; and then what is to drive the mills of the universe?

The Hopeless Theory of a World that Must One Day Utterly Perish

This is the doctrine of the dissipation of energy. It depicts the light and heat of the sun and stars, the comets and nebulæ, gradually becoming exhausted, sinking to a uniform dead level of temperature, where they are not unheated, but where they are useless—as the "mill-wheel cannot turn with the water that is past." It depicts the motion of suns and planets and all other things gradually lost, because of friction, which, as we have lately observed, tends to turn motion into heat. And since the motion of the heavenly bodies, which keeps them in their orbits, must die down, they will all fall together, by the law of gravitation, until the matter of the universe, all the stars, bright and dark, and planets, and everything else, will be gathered together into one immense but impotent heap, not devoid of heat, but all of the same temperature, and therefore inactive. In a word, the clock or machine will have run down; and will have proved itself to be just like man-made machines after all, and not a perpetual motion machine, as we thought the universe must be.

Such is the law of the "dissipation of energy," which is still accepted by the majority of men of science, and was regarded, until very recently, as one of the definite and established results of scientific inquiry. If it be true, it necessarily involves a beginning and an end; and it invites us to accept the appalling idea that

this end is inevitable, a universal death without hope of resurrection.

Only one illustrious thinker in the nineteenth century dared to refuse obeisance to this creed, but he was a thinker indeed. Herbert Spencer never accepted this theory. His objections to it were magnificently stated; and men of science are beginning to echo them, with ever-increasing emphasis, to-day.

Herbert Spencer's Great Faith in a Universe for Ever Renewing its Youth

He showed what the law must mean, if it were true, and pointed to the evidence of the skies, where we see new suns and worlds ever forming, with no sign of old age. Or, rather, he showed that, though "the sun grows cold, and the stars are old," other suns grow warm, and other stars are born. He argued that there must be compensating forces at work which would build up and make new beginnings no less real and active than those which seem to be running down. We all know, notwithstanding the decay of autumn and the "dead of winter," that life is not dead, but is active under the soil, and that spring will return. In some such way, according to Spencer and the few who have always thought with him, there must be forces at work in the universe, even though they be too deep for our eyes, which have promise of rejuvenesence in them, forces through which "the most ancient heavens are fresh and strong."

The advance of scientific knowledge in our century, and even since Spencer's and Kelvin's death, has gone far to weaken the general belief among men of science that the law of the dissipation of energy is true, and that the universe is thus no more than a clock which is running down.

A Great Fact that was Ignored in the Old Pictures of the Universe

Mathematics is a noble science, but its conclusions, when applied to questions as these, depend upon the completeness of the evidence it discusses. Continually the confident assertions of mathematicians are falsified in consequence—as, for instance, Lord Kelvin's assertion that there was nothing to be expected of toys like flying-machines. In the great case under discussion there need be quoted only two universal factors, one of which was unproved until four or five years ago, while the other was never dreamt of.

Though universal gravitation always tends to draw things together, there is a form of energy, called radiation-pressure, which tends to drive them apart. In certain conditions, this force is greater than that of gravitation, so that by it bodies would be scattered, though gravitation was all the while tending to bring them together. Here, evidently, is a fact which was ignored in last century's pictures of a universe all huddled in one dead heap.

Again, radio-activity was unimagined until a few years ago. The forces within atoms, far greater than all the forces outside them, were unknown. The history of atoms, their building up and breaking down, and the consequences of these processes, were not only unthought of, but the suggestion of such possibilities would have been scouted as ignorant and absurd. But no one who has ever glanced at this subject, and the possibilities which it opens up, could possibly permit himself to accept the theory of the dissipation of energy as he might have done only a decade ago. It may yet be shown that the dissipated heat which results from so much of the transformations of energy, and is lost to our use, and appears henceforth unavailable, may play its part in the upbuilding of atoms, and so, in due course, become available again, as in the atoms of radium and many other elements. This is only one of the possibilities that present themselves to our minds in this remarkable and unprecedented era of scientific revelations; and the future will pronounce upon them.

The Everlasting Universe Without Beginning and Without End

If we may dare to anticipate the verdict, it will be that science has no word of any beginning to things, nor of any end; that the universe is indeed a perpetual motion machine, or like a mighty tree which has the secret of the elixir of life; that its processes are balanced and just, "action and reaction, equal and opposite," as Newton said; that it is indestructible, as a whole and in the minutest part; and that, being perfect, it is incapable of addition to its substance. It is thus, in the full sense of the word, eternal, without beginning or end. It was not created out of nothing, nor will it return to nothing, either in substance or in activity; but it is being created and re-created everywhere, and always. This is what we nowadays call Universal Evolution—the greatest idea of the nineteenth century, and one which, so far from suffering injury in recent years, as many nineteenth century ideas have suffered, is to-day more certain, more complete, more momentous than ever before.

ALIVE IN THE DAYS BEFORE MAN

A COLONY OF QUAINT LITTLE TRILOBITES PHOTOGRAPHED ON A PIECE OF BLACK ROCK

Among the oldest remains on the earth is the trilobite, a curious little creature which, as far as we know, was the first king of the animal world. The trilobite, with a very complete and complex structure, had the power of rolling up closely so that its soft body was covered with hard shell. This striking photograph shows a colony of these marine creatures, unearthed on a slab of black rock where they perished millions of years ago, in company with a number of crabs, some of which appear white in the picture.

EARTH'S AUTOBIOGRAPHY

The Rocks which are as Enthralling as a Novel if we Know how to Read Them

LIFE-STORIES SEALED UP IN PAST AGES

SEDIMENTARY rocks are plastered over the surface of the globe, making altogether a layer fourteen miles thick. Fourteen miles of rock are not laid down and raised up in a day, and probably required at least 90 million years for their making. The question arises: Can we divide this immense coating of rock into layers according to their time of deposit?

Naturally and necessarily, the lower strata must, on the average, be the older, and the upper strata must be the newer, but we must not assume, simply because a stratum is on the top, that it has been recently deposited. It may have been intruded through newer rock by volcanic forces, or many newer strata may have been worn off it. Nor can we estimate the age of a stratum from its mineral character. The deposition and elevation of strata has never taken place simultaneously all over the globe; there never was a universal deluge; and America may have been down when Europe was up. Further, even if sedimentation had taken place simultaneously in different seas, and had been simultaneously raised as land, it might yet show very different mineral characters.

No doubt the minerals of the original surface of the globe were variegated, and, accordingly, even the same sheet of sediment may vary in character in different parts of its area. We may find strata six layers deep here, and six layers deep there, resembling one another in their mineral characters, and yet they may be of quite different ages. We may find strata six layers deep here, and six layers deep there, differing from each other in mineral characters, and yet they may have been laid down in identical eras.

Neither from likeness in mineral character nor from likeness in serial position can we assume that rocks are of the same age; and neither from unlikeness in mineral character, nor unlikeness in serial position, can we assume that they are of different ages.

Again, how are we to divide stratified rocks into consecutive layers, each denoting a separate period of deposition? We find stratified rock of a certain depth, but how are we to say whether it were all laid down at one time, or whether it be the product of several different eras? If one stratum be laid on a puckered stratum whose puckers show evidence of wear and tear, we are safe to say that an interval elapsed between the depositing of the former and the depositing of the latter; but in many cases, no doubt, strata belonging to different eras lie continuously and without disturbance upon one another, exhibiting perfect *conformability*—the technical term—and show no division mark to denote their separation in time. The difficulty of separating and arranging strata is greatly increased by the fact that only here and there can we see their edges, and that, as a rule, only a few edges are visible. Even in the Himalayas, and in the Grand Canyon of Colorado, where great numbers of strata are thrown open to view, we have by no means a complete series. As somebody has said: "We are very much in the position of persons called upon to describe the cloth in a warehouse in which they are allowed to finger only the edges of a few bales."

How, then, are we to draw lines and fix dates? The problem was solved more than a hundred years ago by William Smith, often called "the Father of English Geology," a surveyor and canal engineer. In the last years of the eighteenth century many canals were constructed, and in his work of canal making and canal surveying William Smith had many opportunities of studying cuttings. In 1794 he was

appointed member of a commission to investigate the English canals, and in the course of his investigations he travelled more than 900 miles through the country. As a result of his studies, he formulated the principle that strata must be placed in space and time *according to the fossils they contain.*

Fossils are organic remains of plants and animals, preserved in rock, or imprints of organic bodies in rocks. Fossils may be of all kinds and sizes. The mammoth preserved in the ice, with hair and flesh still adhering to its skeleton, the track of a worm marked on sandstone or shale, the sharks' teeth in the deep-sea ooze, are all fossils.

The Signs of Life that are Preserved in the Ocean Beds

In the soil and on the surface of the earth most organic substances decay, and leave almost no residue, but in the bottoms of lakes, in bogs, in rivers, in mineral springs, and in the sea they may be protected in various ways from destructive agencies, and retain their shape, at least, for tremendous periods of time. The sea-floor, and particularly the sea-floor near the shore, is especially likely to preserve organic remains in its constantly accumulating sediment; and it will preserve, of course, not only organic remains native to the sea, but also organic remains proper to the land that have been brought down by the rivers. Accordingly, since the sedimentary deposits were probably laid down on the sea-floor within a hundred miles of shore, it is not surprising that they contain numerous fossils.

When we examine the fossils thus preserved in strata, we find that lower and higher layers contain different fossils, and that they are graded in a regular order as we ascend. We find that all over the world fossils occur in this regular order, and that it is possible to divide strata accordingly, placing any sedimentary rock in its proper position if we know what characteristic fossils it contains. It is the fossil in the rock, more than the mineralogy of the rock, that tells its true position in time and space.

The Four Great Geological Eras in which the Fossils are Grouped

Professor W. J. Sollas puts the matter picturesquely in this way: "A geologist crossing to America and visiting the Falls of Niagara may pick up fragments of limestone which will at once strike him as remarkably similar to certain rocks he is familiar with at home; his thoughts will naturally revert to Dudley or Wenlock, classic localities for Silurian limestone, and he will have little hesitation in asserting that the Niagara limestone has a very Silurian aspect. But when he looks more closely into it, and discovers the fossils it contains, the Dudley 'butterfly,' or the Dudley 'locust,' or the familiar chain-coral, then any doubt he may have entertained will disappear, and he will exclaim: 'This is not merely like—this *is* Silurian limestone.'"

From a consideration of the differences in the fossil contents of sedimentary rocks, the stratified formations of the earth's crust, constituting the geological record, have been classified in the following five main divisions with their various sub-divisions.

Era	Fossils
ARCHÆAN OR AZOIC	
PRIMARY OR PALÆOZOIC	
Cambrian	Invertebrates
Silurian	Invertebrates
Devonian	Invertebrates
Carboniferous	Fish
Permian	Amphibia
SECONDARY OR MESOZOIC	
Triassic	Reptiles
Jurassic	
Cretaceous	
TERTIARY OR CAINOZOIC	
Eocene	Mammals
Oligocene	
Miocene	
Pliocene	Java Man
QUATERNARY OR NEOZOIC	
Pleistocene	Man
Present	

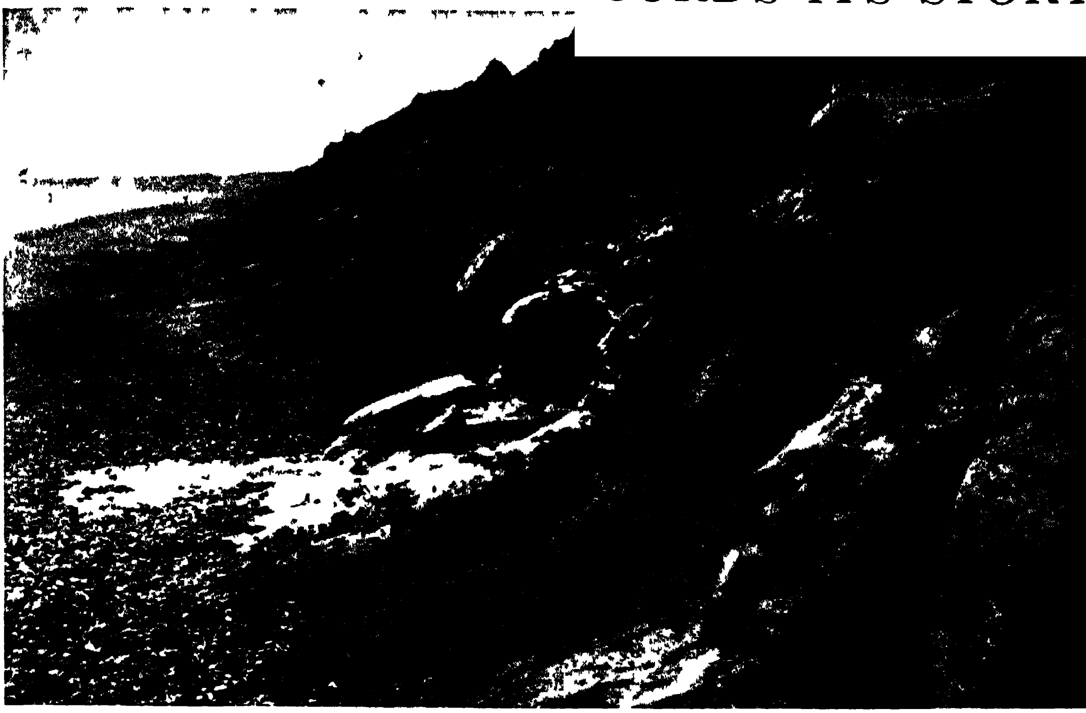
Under the sedimentary rocks we find igneous crystalline rocks, known as the Archæan formation, which might be supposed to be part of the original crust of the molten world, but this is probably not so. All the Archæan rocks we know are almost certainly volcanic in origin, and have probably either burst through the original crust or flowed out through a fissure in it.

Before the Cambrian period there was a tremendous outflow of melted rock, covering all the area of the Lake Superior basin, and building up a series of volcanic rocks 20,000 feet thick. In the Mesozoic period there were outflows that covered the Deccan in India to a depth of 4000 or 6000 feet. In Tertiary times 200,000 square miles in Idaho, Oregon, and Washington were covered to a depth in some places of 2000 feet.

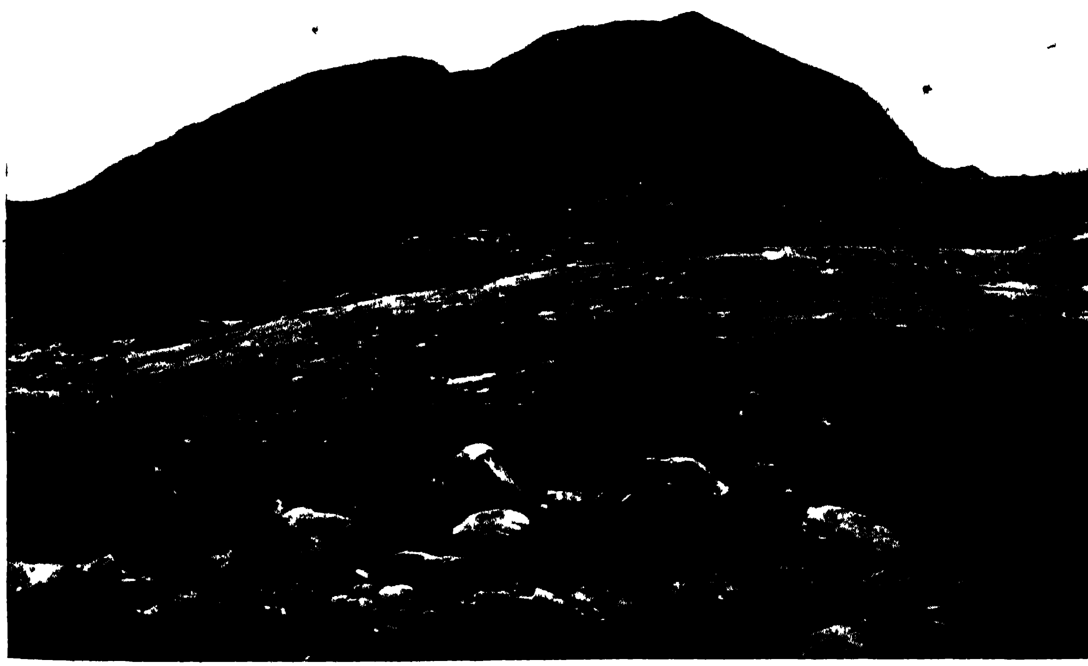
In such a way, and by more localised volcanic action such as we see in modern volcanic explosions, the Archæan rocks were made; and we have no knowledge whatsoever of the real original crust of the earth beneath its load of cinders and mud.

In the Archæan rocks no fossils are

HOW THE EARTH RECORDS ITS STORY



HUGE BOULDERS ON THE HAMPSHIRE COAST MARKING THE BED OF AN ANCIENT RIVER



THE TRACK OF A GLACIER THAT CREPT OVER ENGLAND IN THE ICE AGE

Many chapters in the history of the past are clearly recorded in the rocks. We know from the huge boulders wedged in the Barton Cliffs that a river must have flowed along the bed now high above the beach, and we know from the markings on the rock at Achnashellach, Ross, shown in the bottom picture, that a glacier must once have crept over this part of Britain, perhaps about half a million years ago.

found, but there can be little or no doubt that during the Archæan period low forms of life did exist. We do not know how life began, or when it began, but it certainly began ages before the Cambrian period, for the animals found in the Cambrian deposits represent quite an advanced stage of animal evolution.

The Primary era is the era of Mollusca, Crustacea, and some strange fishes, and amphibians; the Secondary era is the era of reptiles; and the Tertiary and Quaternary eras are the eras of mammals.

Where the Oldest of All the Fossils in the Earth are Found

In the vast sedimentary deposits below the Cambrian rocks no fossils have been found, but there can be little or no doubt, nevertheless, that in the periods represented by these deposits there must have been multitudes of invertebrate animals in the world, for, as we have already mentioned, the animals found in the Cambrian deposits represent quite a forward stage of evolution.

Let us now take a general survey of the four great geological periods.

THE FIRST PERIOD. In the Cambrian rocks of this Primary or Palæozoic formation period the oldest known fossils are found. These consist chiefly of shell-bearing molluscs and of highly organised creatures such as water-fleas and trilobites, but there are also to be found a few sponges, worms, and water-plants. Trilobites are perhaps the most characteristic fossil of the primary strata. They are a kind of blend between a king-crab and a wood-louse, and have a three-lobed appearance—from which they take their name—and several pairs of slender legs. Some are blind, and some have huge eyes. Some are almost microscopic, and some are almost two feet long.

The First Record we can Find of a Special Organ of Vision

One of the common features of all trilobites is the possession of a head-shield which, except in some blind genera, bears a pair of large compound eyes. In some the eye is more or less conical, and in others it is crescent. Several types of eyes of very complicated structure have been recognised. In some the eyes have fourteen lenses only, while others have as many as fifteen thousand. The eye of the trilobite is the first record we possess of the presence of a special organ for the perception of light, and we see what a wonderful and complex organism it is. How long life must have been in building up this structure we do not know; but it is wonderful to think of the marvellous processes of evolution that must have been going on far beyond the first appearance of the trilobites, which are among the first living things of which we have any record.

The greatest extent and depth of Cambrian rocks is found in Wales, and the deposit which made this rock was no doubt drained into the sea from a land to the west.

In the Silurian period we find great numbers of molluscs and crustaceans, also sponges, starfish, sea-urchins, and foraminifera. Here, for the first time, fishes appear —strange fishes with no bony skeleton, with no lower jaw, and covered with a kind of plate armour. Fossil ferns and lycopods also are found, and a scorpion with a poison gland and sting; also a true insect wing. The fact that the scorpion has a sting proves that there must have been other land animals to sting.

The Devonian and Carboniferous strata are characterised by luxuriant land vegetation, and a large number of insects and crustacea. In the Carboniferous era most of the great coalfields were formed; and it is probable that at this time there was an excess of carbon dioxide in the atmosphere which increased the temperature and favoured vegetation, so that ferns, horse-tails, and club-mosses grew to a great size.

The Grotesque and Monstrous Things Found in the Secondary Rocks

Among the insects in the tropical jungles were ancient forms of spiders, millipedes, centipedes, mayflies, cockroaches, crickets, beetles, moths, and butterflies. Scorpions of gigantic size also abounded. In the seas and lakes were many fishes. But the most interesting animal fossils of this period are strange amphibians rather like lizards or salamanders, with long tails and weak limbs. Some of these are only a few inches long, others are seven or eight feet in length.

In this period, also, in the Permian strata, the first reptile is found—the Proterosaurus.

THE SECOND PERIOD. The rocks of the Secondary or Mesozoic period contain the records of Nature's experiments in reptiles. No other strata contain such grotesque and monstrous forms. Here we find the iguanodon, a lizard-like animal about thirty feet long, that walked on its hind legs, and had a powerful muscular tail like a kangaroo. Its teeth and bones, it is interesting to note, were first found in Sussex, but no less than twenty-nine iguanodons were found in a colliery in Belgium. Here came the plated

THE REAL RULERS OF THE WATERS IN THE EARLY DAYS OF THE WORLD

Some of the strange creatures that lived in the sea millions of years ago reached a length of 75 feet or more, and had, like snakes, rows of formidable teeth in the roof of their mouth, used as weapons for seizing their prey. The saurians and sea-serpents, says Professor Geikie, were the real rulers of the American waters in the Cretaceous Age.

lizard, or Stegosaurus, the amazing Brontosaurus, fifty-five feet long, and seventeen feet high, and twenty tons in weight, with the smallest head in proportion to its body of any animal known. Here came Diplodocus, eighty feet long, with an enormous neck and an equally enormous tail. In the Cretaceous rocks of Western North America reptiles are particularly abundant.

According to Professor Geikie, the real rulers of the American Cretaceous waters were the pythonomorphic saurians and sea-serpents. "Some of them," Dr. Geikie says, "attained a length of seventy-five feet or more. They possessed a remarkable elongation of form, particularly in the tail; their heads were large, flat, and conic, with eyes directed partly upwards. They swam by means of two pairs of paddles, like the flippers of the whale, and the eel-like strokes of their flattened tail. Like snakes, they had four rows of formidable teeth on the roof of the mouth, which served as weapons for seizing their prey. But the most remarkable feature in these creatures was the unique arrangement for permitting them to swallow their prey entire, in the manner of snakes. Each half of the lower jaw was articulated at a point nearly midway between the ear and the chin, so as greatly to widen the space between the jaws, and the throat must, consequently, have been loose and baggy like a pelican's."

Equally monstrous were the turtles, some of which measured more than five yards between the tips of their flippers.

And even more monstrous were the bird-lizards, or pterodactyls—lizards that flew about like bats, and in some instances

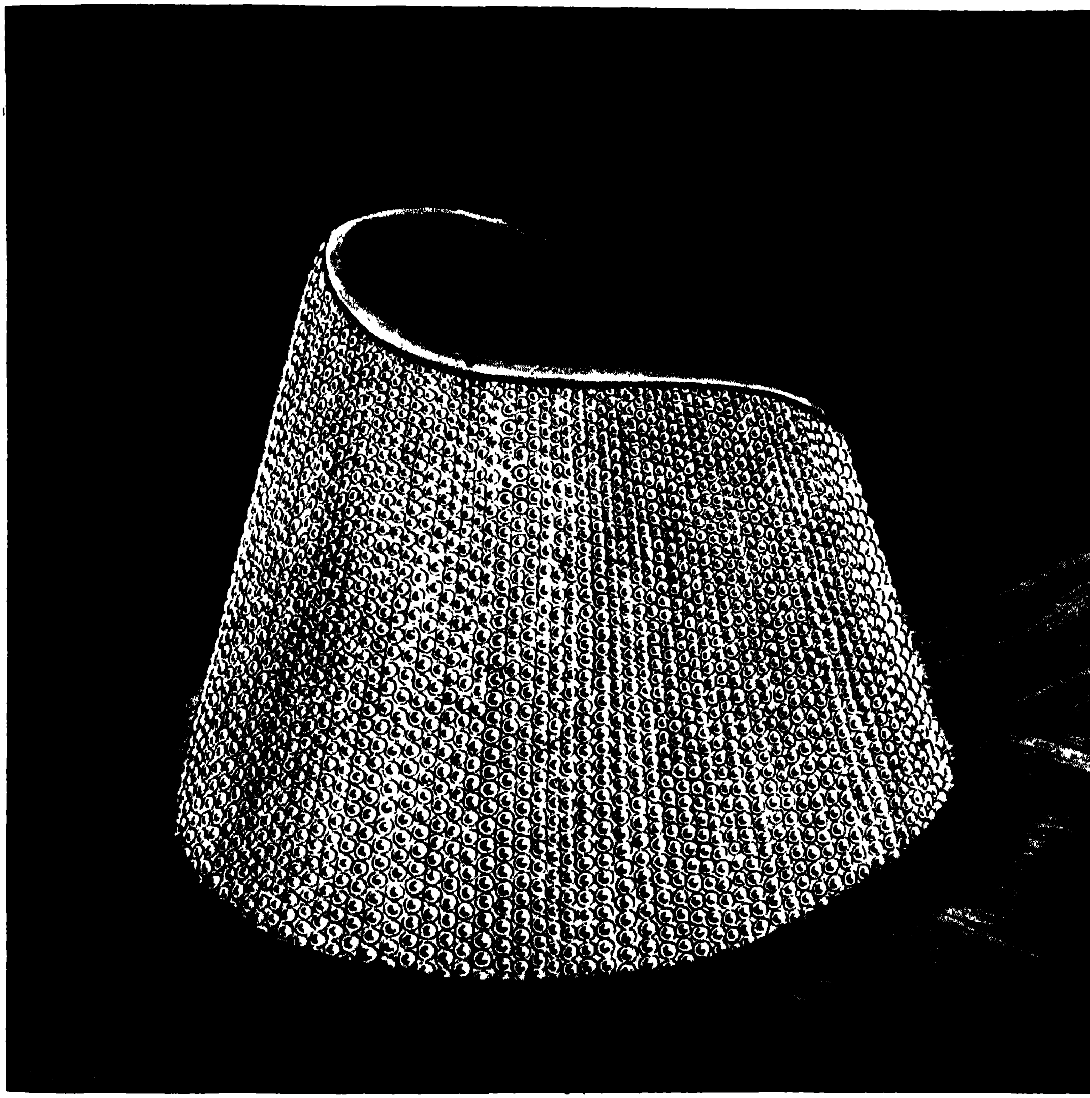
AN IDEALISED PICTURE OF THE EARLY DAYS OF THE WORLD, WHEN THE FOSSILS WE FIND IN THE ROCKS WERE SWIMMING IN THE SEA

THE NEEDLE PEAKS OF THE GRAND CHARMOZ, TO THE EAST OF CHAMONIX, SWITZERLAND

From a photograph by Donald Macleish

measured twenty feet between the tips of their wings. It must have been a strange, weird world then!

But not all the fossils of the Mesozoic formation were records of monstrosities, for in this era appeared the first true birds and the first true mammals. The oldest bird known, the Archæopteryx, was rather smaller than a crow; it had a long, lizard-like tail; its wings had free claws, and its jaws had teeth. The first mammals were small, and belonged to the same types as the kangaroos and opossums, and moles and shrews, and duck-billed platypus. Perhaps the most characteristic fossils of the Mesozoic formation are the ammonites and belemnites—shells of certain molluscs. In the British Lias rocks alone there are some hundreds of species. Sponges also swarmed on the floors of the Cretaceous seas, and the flints found in limestone are products of these. Among other insects, dragonflies, mayflies, cockroaches, beetles, and butterflies are found. The vegetation in the Mesozoic period was luxuriant. Ferns, club-mosses, horsetail reeds, cycads abounded, besides oak, willow, fig, walnut, plane, laurel, beech, maple, magnolia, and other trees.



THE EYE OF A TRILOBITE GREATLY MAGNIFIED—A MARVEL OF LIFE FOUND IN THE ROCKS

Nothing that we find in the rocks, telling us dimly the story of life, is more wonderful than the eye of a trilobite, one of the earliest created things still preserved in the earth. This eye is the first record we possess of a special organ for the perception of light, and we see what a complex organism it is. How long life must have been in building up this structure we do not know; it is wonderful to think of the marvellous processes of evolution that must have been going on far beyond the first appearance of the first living thing we know.

THE THIRD PERIOD. In this period there were tremendous upheavals of the

sea, and most of the great modern mountain-chains were made. Not only were Cretaceous deposits raised into low lands, but "from the Pyrenees to Japan the bed of the early Tertiary sea was upheaved into a succession of giant mountains, some portions of that seashore now standing at a height of at least 16,500 feet above the sea."

Almost all the big weird reptiles have died out; and it is now an age of big mammals. Not only have the monstrous reptiles died out, but all animals, large and small, have changed, and have come much more to resemble the animals of modern times. Still, however, monsters that have not survived to present days continue to be produced. Among these were mastodons, mammoths, sabre-toothed tigers, and tortoises six feet long. In the Miocene deposits apes are found.

The vegetation of this formation is tropical or sub-tropical.

THE FOURTH PERIOD. The Pleistocene period of the Quaternary or Neozoic formation is also known as the "Ice Age," since at this time the whole of the wall of Europe was covered with ice.

When England was Lost under Ice nearly a Mile Thick

The ice-sheet reached almost as far as London, and as far as Lyons in France. From the Alps and the Pyrenees colossal glaciers descended. Canada and the United States, down to the 39th parallel of latitude, were likewise under ice. In Europe alone nearly 800,000 square miles were out of sight. Nor was the coating merely thin. In Scandinavia the ice was 6000 or 7000 feet thick, and in England 4000 or 5000 feet thick. Glaciers were everywhere, and the main masses of ice themselves moved in glacier fashion, grinding and scratching as they went. The soils were pushed away, the rocks abraded and eroded, and the valleys deepened and widened. During the glacial period various land areas subsided under the sea and were again elevated.

When the ice was at its height no doubt all the northern vegetation was killed, and all the animals of the northern hemisphere migrated south. Reindeer wandered about Switzerland, and the arctic foxes found a congenial climate in the Pyrenees.

As the climate became less severe, elephants, mammoths, hippopotamuses, woolly rhinoceros, lions, bears, boars, and bisons appeared in Europe, but their reign was short. In caves in the Dordogne, in France, and elsewhere, bones strewn on the ground have been found; and carvings of some of the bones show that the cavemen hunted and ate the mammoth, the reindeer, the elk, the horse, and the bison.

We have spoken of the glacial epoch, but there were really several glacial epochs —some say three, and some seven—with more genial periods between.

Man, we have said, must have lived in this epoch, but few traces of man have as yet been found—a few skulls and jaws, and flint weapons known as "eoliths."

The Laying Down of the Fossil Beds in Different Countries

When we consider the great geological epochs, as described by the fossils in the sedimentary rocks, we must not make the mistake of supposing that all rocks containing the same fossils were laid down and raised up at the same time. In any part of the world the fossils occurring in any superimposed series of formations have a definite serial relation to each other, but one cannot say that similar fossil beds in different countries were laid down contemporaneously. Rather the reverse, for, since each form of life probably sprang into existence in some particular region, it must have taken time for each to spread to other regions. If we assume, for instance, that an animal took origin in Africa, and spread to America, and if we find fossils of the animals both in Africa and America, it is plain that the American must be later than the African.

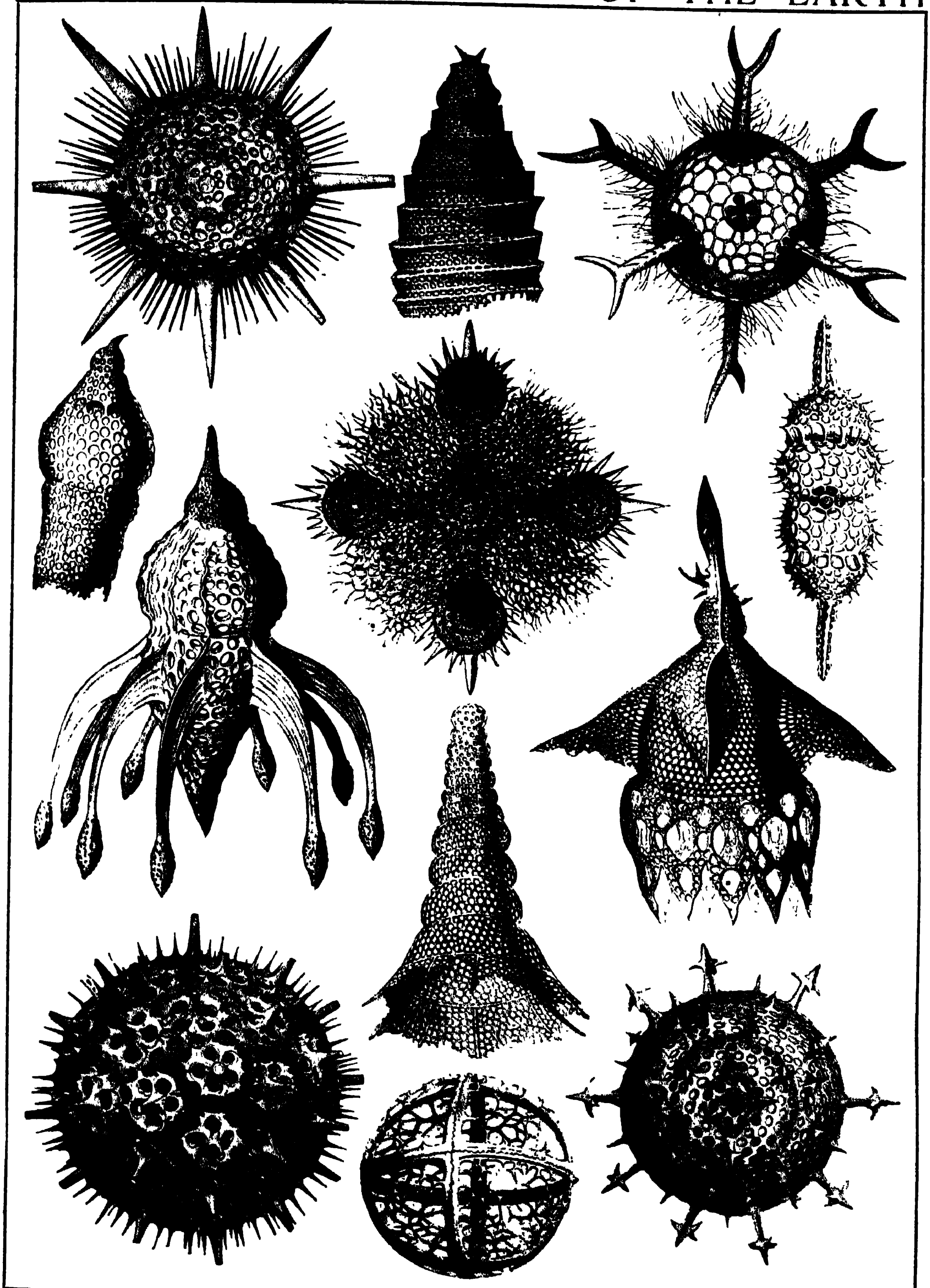
All these depositions and elevations of sediment that produce the different formations, with their fossil contents, necessarily imply constant changes in the geographical formation of the earth.

A Traveller Walking from India to Peru who would not See a Mammal or a Flower

Among palæozoic lands was the palæozoic continent known as "Gondwana Land," which consisted of South Africa and a large part of Central Asia, together with Madagascar and the Indian Peninsula; and it is quite possible that "Gondwana Land" joined to ancient South America through a continent in the South Atlantic, known as South Atlantis. If this were so, one might have gone by land in these days from India to Peru; but not a single mammal or flower would one have seen the whole way, only a few strange monsters and reptiles lurking in the primeval jungles.

China, Mongolia, and Eastern Siberia are also of palæozoic date, and formed a continent known as Angaraland; and at this

FORMING A NEW LAYER OF THE EARTH



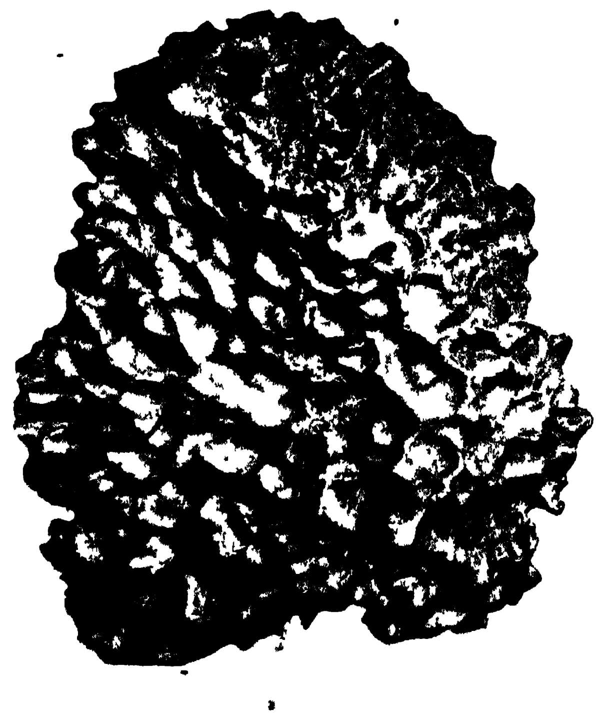
These beautiful things, magnified from specks invisible to the eye, were homes of the creatures that built them. Inhabiting the sea in untold billions, they die and accumulate in thick layers, forming limestone, which may one day be dry land in which some geologist of the future will find fossils of our time.

THE COAL FORESTS OF MILLIONS OF YEARS AGO—AN IDEAL PICTURE OF THE CARBONIFEROUS AGE

In the Carboniferous era most of the great coalfields were formed, and this is how a coal forest must have looked. Fossil trees are still found standing in coal seams, unquestionable proof that a coalfield is a fossil forest, and not merely vegetable matter washed down, as was once supposed to be the case.

time the North Atlantic was probably occupied by a great continent—Atlantis. In early Mesozoic times there was a great sea named the Sea of Tethys, the ancient Central Mediterranean, between Gondwana Land, Angaraland, and the European part of Atlantis. Towards the middle of the Mesozoic times the bottom of this great sea heaved up and formed Asia Minor, the mountain regions of the Hindu Kush, the Pamirs, the Himalayas, and the Trans-Himalayas, thus completing the continent of Asia. The modern Mediterranean is a relic of that mighty sea. What an upheaval it must have been that made the Himalayas!

At the end of the Mesozoic period, also, North America emerged from the sea. In the Cretaceous period it was covered by the sea from the Gulf of Mexico to the Mackenzie River, and perhaps as far as the Arctic Ocean; and when the ocean bed rose a large inland sea, known as "Lake Laramie," was left in the centre of the new continent.



A PIECE OF ROCK FROM ANOTHER WORLD

This photograph is of a piece of rock that has fallen on our earth is a meteorite which proves on analysis to be composed of the same materials as those which comprise the rocks of the earth.

Even in Quaternary times, when prehistoric man was chipping his flints, the world's geography was very much unlike its geography now. In those days Europe extended far westwards of the British Isles, and the Irish Sea, the English Channel, and the German Ocean were wide valley plains watered by noble rivers. The Rhine, with its tributaries the Elbe and the Thames, flowed northwards and opened into the sea near the Faroe Isles, and the Seine flowed along the valley of the English Channel, to enter the Atlantic a hundred miles west of Land's End. There

was no Adriatic, and the Mediterranean was divided into two by a belt of land which stretched across from Africa to Europe. Asia was probably united to America across the Behring Straits, and Europe was perhaps still united to North America by Atlantis. A traveller could have gone, with the aid of a small canoe, all the way from London to Tasmania. Professor Sollas gives us an interesting picture of what a traveller could see in these early times:

"Even before leaving England he would see strange sights on the way: great herds of elephants of an ancient kind, the mightier predecessors perhaps ancestors, of the mighty African elephant; he might witness, not without awe, the infuriated rush of the soft-nosed rhinoceros, which bore a horn sometimes as much as three feet in length; disporting itself in the rivers was that shy behemoth the hippopotamus, the mother animal swimming with her young upon her back; sometimes he might catch sight of the great sabre-toothed lion making its stealthy spring, or hanging on to the flanks of a strayed elephant. A delightfully warm, open climate might tempt the traveller to make his bed in the open, but in any case he would do well to beware, before accepting the shelter of a cavern, for there he might encounter the terrible cave bear, larger than any existing species, or an animal still more terrible, no other than man himself."

THE MARVELLOUS PRESERVATION OF STRUCTURE

The first of these two microscopic photographs shows a piece of wood a few years old; the second shows a piece of coal millions of years old. Under the microscope the structure of one resembles the other in a remarkable way, showing astonishing preservation of delicate structure, through countless ages, deep down in the pressure of the earth

But perhaps nothing gives us a better idea of the protean changes in the surface of the globe than a comparison of the geography of Britain at different epochs. In early Carboniferous times, all Ireland, and most of Britain, including all the Southern and Eastern Counties, were under the sea; the North of Scotland was part of a mainland, and the Irish Channel was dry land. In Triassic times almost the whole of Scotland and Ireland were above water, but almost all England, except Wales, and the south-west and south-east, were under the sea. While in Tertiary times the south-east corner of England was submerged, and all the rest of the British Isles above the sea, and connected with Norway and Iceland by broad belts of land.

THE WORK OF FIRE AND WATER - VOLCANIC ROCK THAT HAS MADE ITS WAY THROUGH THE CRUST

Many of the archæan rocks we know are volcanic in origin; and this photograph, taken in Fifeshire, shows how these fire-formed rocks crept through the original crust, or flowed out through a fissure, in the days when the British Isles were being laid down. The marks on the sandstone to the left were made by the sea in prehistoric times, so that here we see the action of fire and water side by side.

SOCRATES THE IMMORTAL GOES OUT INTO THE UNIVERSE

"WHERE SHALL WE BURY YOU ?" THEY ASKED SOCRATES BEFORE THE EXECUTIONER CAME. "WHERE YOU WILL," SAID HE; "IF YOU CAN CATCH ME!"

Reproduced from the painting by L. David, by permission of Messrs. Braun Clement & Co.

WHY THE BODY MUST DIE

The Meaning of Physical Death in the Scheme of Nature, and the Place of the Individual in the Scale of Ascending Life

FROM BIRTH TO DEATH AND DEATH TO BIRTH

LIFE can only exist under certain conditions, and if these be lacking it ceases. A great part of all death is due to this cause—to battle and murder and accident and starvation and poisoning. Some of these forms of death are of the utmost importance in the history and progress of life, for the death by murder of one species may mean the life, the well-fed life, of another; and death by starvation raises the whole question of the struggle for food, which is half the drama of the world.

But here we are faced with a different question, which is concerned with the fact of what we may call natural death. This is not to say that the other forms of death are unnatural, but we require a special term to indicate the form of death which is due to no accident or murder or lack of the needs of life, but depends upon an internal and inevitable necessity in the nature of the living thing. Unless we once for all grasp this fundamental distinction between "natural" death and all other forms of death, we shall never be able to unravel and understand our problem—the problem of death—as one of the universal and appointed facts of life.

We require definitely to satisfy ourselves that there is such a thing as natural death. In our own lives we are beginning to learn that death may often be averted, and that the greater part of human death is, at the least, premature. We may almost be excused for rushing to the conclusion that, if only we knew still more about diet, and "auto-intoxication," and all the rest of the vocabulary of the modern food-reformer and "health-culturist," we might avert death indefinitely. And among the humbler forms of life we see death so constantly due to accident, change of weather, starvation, and, above all, to the attacks of other life—as when the bird eats insects or the cat the bird—that there also we may suppose that, if special protection were afforded, any living thing might continue to live on indefinitely.

But it is not so. We may admit that wiser and better conditions—not necessarily *easier* conditions, but that is another and a tremendous story—would prolong the span of life for almost all individuals of all species, but not indefinitely. We observe that our domestic pets grow old from maturity as inevitably as they grow up from infancy. It is as definitely part of the preordained and unchangeable nature of the cat that it shall grow old *and die* as it is part of the nature of the kitten that it shall grow to be a cat. The necessity of natural death is thus in the kitten, and was in it from the first instant of its individual life. We are all necessarily walking to our own funerals, so far as physical life is concerned; and what is true of all forms of animal life is true also, though with some qualifications, of all forms of vegetable life. Death is one of the inherent attributes of life.

We are thus faced with a paradox, the greatest paradox in Nature. Having surveyed the living world, we saw at least as far as this—that life will not give in, that it ever demands more and more expression, and that all its attributes exist for its service.

The leaf of the plant, the claws of the tiger, any attribute or characteristic, without any important exception, of whatever living creature we choose to study—all exist for the furtherance, enhancement, multiplication, aggrandisement of life. Yet at the very outset of our study, and without a moment's interval after we have realised this concentrated, unshakable, devoted striving of all the living world and all its attributes, we find ourselves faced with death, which is at least as universal a fact of living things as any that we can observe.

If this be an exception to the rule, it must either, in some apparently incomprehensible fashion, be an exception that proves the rule, or else it must break the rule altogether. How can we regard "more life and fuller" as the aim of all life if we find that all living beings are constructed and intended to die?

As we shall learn later, the living world displays characteristics which compel us to believe in what is called "natural selection," or "the survival of the fittest." According to this doctrine, not merely are living things made in order to achieve as much life as possible, but all existing forms of life are the survivors of an age-long struggle in which victory always goes to those that are "fittest"—those that have the greatest numbers of features which enable them to survive. We therefore speak of the "survival-value" of a backbone, or a trunk, or an instinct, or a wing, or an intelligence, or a tearing tooth, or any other feature of any individual of any species. It is true that, since this doctrine was first stated, we have learnt to see that sometimes new forms of life appear which may not have any survival-value of their own—say, for instance, toy dogs, some of whose features are a handicap, and would be fatal in the ordinary way.

The Survival-Value of Death which has Enabled it to Persist and to Make for more Life

But though we must note this lest we find ourselves in contradiction when we come to consider the principles of Mendelism, no one questions that the great and general characteristics of living beings have been formed under the influence of natural selection, which has always and necessarily favoured the survival of whatever made for life, and has incessantly and ruthlessly pruned away whatever made for death. Yet this character, death, has survived in the struggle for existence; and the law of the "survival of the fittest" must either be nonsense, or else we must demonstrate what seems the utmost absurdity—the survival-value of death.

Evidently we cannot mean the survival-value of death to the oak or herring that dies. Its death cannot promote its life. But it is possible that its death may promote the life of the species to which it belongs, and thus death would mean, in the long run, the making of more and fuller life. The great student and thinker who first tackled this tremendous question was August Weismann, the German biologist, to whom our knowledge of heredity is so much indebted. As a devoted follower of Darwin's doctrine of natural selection, Weismann saw that this doctrine must either be abandoned or it must be proved that death makes for life, and has thus been encouraged by natural selection, just like the other characters of living beings, locomotion, sensation, teeth, and what not, which obviously make for life.

Weismann's famous essay was written a long time ago; and here we may restate the case as it can be seen to-day, only we must remember our debt to this great man, who still lives and enjoys the homage of all students of life throughout the world.

The Birth of Death, and the First Living Things that do not Die

Substantially, indeed, we can add nothing to what he showed many years ago; and certainly we must follow his method, which was to trace the forms of life up from the humblest known, and thus to explain death, by discovering its birth. For Weismann showed that death was not part of the living world at first. It has been evolved, as backbones and brains have been evolved; and the key to it lies in its origin, in the circumstances which led up to the birth of death.

We have already seen, as Weismann was the first to point out, that the single-celled creatures, which divide into two and so continue, do not die. Death, as we understand it, does not occur at all. The individual amœba, or bacillus, disappears, but no part of it has died. These creatures are, therefore, in a sense immortal. What we mean by natural death has not come into the world at this stage in the evolution of life.

But among both plants and animals we find that these single-celled creatures become the ancestors of higher forms, made of many cells, some of which discharge one function and some another. The whole case is now necessarily changed.

The Ceaseless Succession of Individuals that Make up the Race

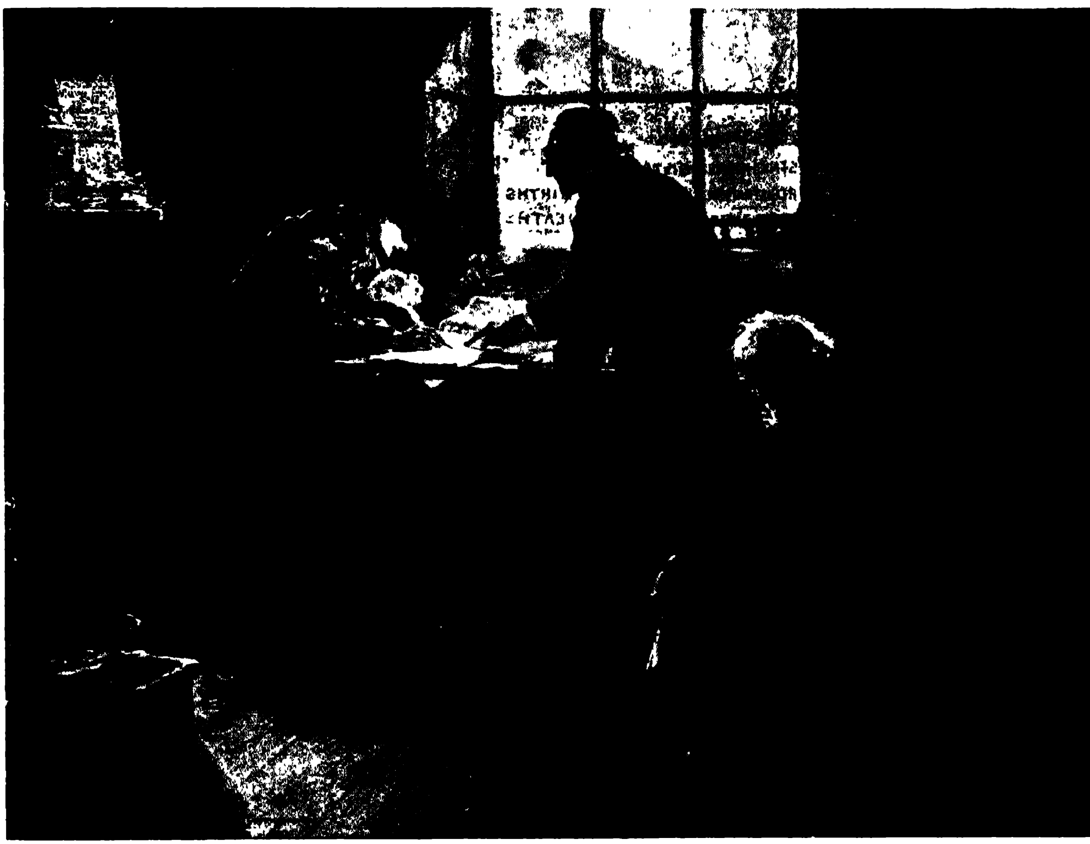
The cells of a feather, or of the skin, or of a tree are evidently incapable of forming a new bird or bat or oak. They are specialised or differentiated, as we say, for a particular purpose, and what is true of them is true of the body of the individual as a whole. Yet the original tendency, which we saw in the microbe or the amœba, persists. That tendency was to grow and grow, until the only way in which yet further growth could be attained, and more life achieved, was by cell-division. And this tendency to cell-division, and the birth of new life, persists in oak or whale or man no less intensely

and inevitably than in bacillus or microbe. In every living species whatever, this making of more and more life is the dominant need and purpose; and the key to death is that it is only the passing of an individual, not of the race, and that it is better for the race that the individual should pass away.

This is what we must now prove; and to that end we must ask ourselves what the individual is, from the point of view of life as a whole.

If we look at the simplest individuals, such as a microbe or amœba, the race is simply a succession of such individuals, and performed his or her task for life, and may disappear. Indeed, it *must* disappear, as we shall see, if the best interests of life are to be served, and its death therefore directly serves and extends life as a whole.

These are ideas of the importance of individuals so revolutionary that they require solid proof, and that proof is now forthcoming. All students of life are agreed that Weismann's profound interpretation is the true one. He taught us to see the potential "immortality" of the unicellular forms of life. One must insert the word "potential," since, of course, any living thing



THE REGISTRAR OF BIRTHS AND DEATHS—FROM THE PAINTING BY RALPH HEDLEY

it is impossible to distinguish between the life and interests of the race and the life and interests of the individual. But directly we go any higher, we find that only a tiny part of the individual is set apart for the future. Such parts are called the "germ-cells"; and, indeed, they are the race. The individual's body is not the race; it is the temporary host or trustee or vessel of the race, and its business is to take care of the germ-cells, or "germ-plasm," entrusted to it, and hand them on unhurt to the future. When that has been done, the individual has may be killed. But these forms of life know nothing of natural, designed, predestined death.

Now, the germ-cells, which are cared for and sheltered and fed in the bodies of individuals of all species above the single-celled microbe and amœba, and their like, really correspond to the sequence of individuals among the amœbas, or microbes, while the body of the individual simply shelters the successive generations of this still one-celled race. Therefore we may speak of, and recognise, the "immortality of the

germ-cells," corresponding to the "immortality" of the single-celled species. Nature, as Tennyson saw long ago, is "careless of the single life," but now we see why. Nature is only careless of the single life, or individual, because she is careful of the race. She therefore considers the individual only in the interests of the immortal race of which the individual is the host; she constructs all individuals not in their own interest—as we are apt to suppose—but in the interest of the race and the future.

The Unfailing Renewal of Life which is the First Great Law of Nature

They are not made for themselves, but for parenthood; and, when they have discharged all their duty to the race, they cumber the ground. Let them pass away and their bodies be resolved into their elements, and nourish the future—perhaps even the new individuals to which they have given birth.

If we look at the facts, we find that they justify these at first sight impossible assertions. The common saying that self-preservation is the first law of Nature is simply untrue, and it is one of those untruths which contain just enough truth to obscure the real truth. The preservation not of the self, the individual, but of the race, is Nature's first law. If we survey the living world as a whole, we find that self-preservation is subordinate to, and exists in order to serve, the preservation of the race. The unfailing renewal of life—that is living Nature's first law. The instinct towards this end, sometimes called the reproductive instinct, and oftener still, by a most unfortunate misinterpretation of its very essence, called the sexual instinct, is best called the racial instinct. It is the instinct requisite for the continuance of the race; and not hunger, but this instinct, in all its forms, is the dominant passion of the living world. In mankind, that unique being, this instinct may take many forms, and may become almost unrecognisable; but whether it remain crude and primitive, as lust, or become transfigured and idealised as love, it has its æonian roots in life's imperative impulse towards more life and fuller.

One of the Ways in which it is True that it is Love that Makes the World go Round

Following this dominant impulse, we accordingly find that, everywhere throughout the living world, "self-preservation" takes a second place. In many species the very act of fatherhood or motherhood involves the immediate death of the individual. In any species the certainty of death, the presence of desperate danger, may be ignored when it comes into competition with the transcendent claims of the instinct which maintains the race. We say that "Love makes the world go round"; and of the many possible interpretations of that saying, one at least is wholly true—that the impulse towards the renewal of life is the dominant tendency of the living world.

In the long run, and on the whole, it must follow that the individual is measured, and its fate sealed, in accordance with the decrees of this supreme necessity, beyond which there is no appeal. In many species, as we have seen, the fathers die directly their task is done. In others, as the beehive teaches, the fathers are deliberately killed by the foster-mothers directly they are of no more use to the maintenance of the race. Their further life would starve the next generation. All the food must be saved for the young grubs; the drones must not be kept another day to consume the children's food. In other cases the fathers are of use not only as more or less mechanical trustees and transmitters of the germ-plasm which has been entrusted to them, but also as unselfish and devoted workers in the interests of their offspring. In species whose fathers have attained this status, the fathers do not die as they otherwise would, but live to see and serve their children.

The Service to the Future which Ultimately Justifies all our Lives

Of course, we are here speaking of the normal and healthy principles of life. The human father who allows his wife to support him, eats his children's bread, and, in a drunken fit, throws the baby at its mother's head, has hardly a parallel in Nature. He outrages all her laws, and is in every just sense the inferior of the microbes which track him down at the last. Yet our very detestation of such things, and our intense sense of their wrongness, testifies in itself to our unexpressed perception that fathers and mothers—which would normally mean all individuals—are made for the future, and are justified of their own lives by their service to the future. That is Nature's judgment with all her creatures, with flower or insect, or bird or fish; and it is none the less significant that our judgment of each other should instinctively conform to Nature's, which is hundreds of millions of years older than the human species.

Yet one more illustration is pertinent. Parents often regret that their children requite their love and devotion with such lukewarmness. The man in his maturity,

THE MAN WITH THE SCYTHE—BY MR. H. H. LA THANGUE, R.A.

or the boy at school, does not love his mother as she loved him in childhood. The parental instinct is one of the dominant facts of our nature. The "filial instinct," which should correspond to it, does not exist at all, though the name has been supplied for it. Children or adults may love their parents, may be grateful to them, may feel tender to the old, but there is here no real correspondence with the feeling of parents for children, or of all normal people for young and helpless life. Indeed, if we nowadays take care of helpless old people, that is not the "filial instinct," but it is the parental instinct, directed in us towards those who are in their second childhood.

In a word, Nature safeguards the future; she leaves the past to take its chance. In vain does the mother long for the return of such love as she gave her son. That love was implanted in her for the race; but, her duty done, she must be thankful for what love and devotion she can get. To all this there is a tragic side, and in many respects man may better Nature here, but the meaning of the facts is clear.

If we accept this reasoning, we are still faced with another difficulty. Let us put on one side the unique case of self-conscious and personal man, and, considering such forms of life as the oak, the swallow, the herring, the fern; let us ask: Why cannot life be content with individuals, and make the most of them, instead of persistently making fresh starts and destroying her previous attempts? The whole process seems so wasteful, and so constantly self-

ONE GENERATION GOETH AND ANOTHER COMETH, AND THERE IS REST FOR THE WEARY

THE HARBOUR OF REFUGE—FROM THE FINE PAINTING IN THE TATE GALLERY, BY FREDERICK WALKER, A.R.A.

annulling, as if one wrecked with the left hand what one made with the right.

But let us observe that, with and through and alongside of all this ceaseless succession of birth and death, of effort to make fine forms, and destruction of them when they are made, *life ascends.* Throughout the ages there is a process which we call evolution, and on the whole the fruit of that process is progress, "more life and fuller." If we look at the steps and stages by which life thus attains what we have agreed to be its evident and persistent purpose, we shall see that it could have been attained, and will in the future be attained, only by the method of finite individual lives, and an endless succession of fresh starts—*some of which may be an advance on anything that has gone before.*

The Universal Fact of Death that Exists in the Service of Life

Only by the method of reproduction can life achieve new forms. Germ-cells vary, and if they get the chance they will develop a certain number of individuals which surpass their parents. Here, and here alone, is the possibility of all progress. All evolution depends upon variation. If there were no reproduction, there could be no variation; and if there is to be reproduction, the reproducers must make way for the reproduced, the parents for the children. As the French proverb has it, "youth will be served." It is the universal law of life, and it is, as we have now proved, the necessary and fundamental condition of all progress. The paradox which we have called "the survival-value of death" is therefore justified; and we see it to be one of the greatest services—however little recognised as yet—of modern biology to the human spirit to have interpreted death in this truly magnificent fashion, as the servant and ally of life and the handmaid of progress. If new forms are to come, old forms of all plants and animals must make way for them, good though those forms may be in themselves, and better than any that went before them. They have not existed in vain, though their lives seem so short, and though they might incline to ask, if they could, why they were born merely to die.

The Living were not Born to Die, but to Beget Better Life

They were not born merely to die. That is not life's idea. On the contrary, they were born in order to beget better life than their own, in order to serve the future and take another step towards realising the utmost that shall be. And since individuals, however ephemeral, are thus necessary for her purpose, Nature rewards them well, makes life sweet, and the renewal of it and devotion to it sweeter still, and hides completely from them the knowledge of death. So pleasant, indeed, does she make even this terrestrial portion of life allotted to her self-conscious marvel, man, who can foresee death, and taste its agony afar, that even this life is well worth while, and "a pleasant thing it is for the eyes to behold the sun."

Lest the reader should not have given the intended weight to those qualifications which the fear of lending colour to unscientific materialism has required us to make in the foregoing statement of physical death, let it be most clearly laid down now that we have here been considering death as a terrestrial fact, a fact actual, indeed, but physical, essentially material, and of things seen. It is the common lot of all forms of life, high or low, admirable or horrible. Certain dispositions of matter, which we call their bodies, cease to exhibit their former powers, and fall to pieces.

The Everlasting Mystery that Lies Beyond Physical Death

That is the evident fact of physical death, of which the foregoing is the interpretation offered by modern science. The only death that physical science knows is physical death—death of the body. That apparently wasteful and cruel process is here interpreted as being a necessary condition of the coming of finer and higher bodies in the future.

But of the death of That, whatever it be, which animates the bodies of living things, science has no record or evidence. It only knows, what all men know, that bodies in which life showed itself fail to display life longer, and fail even to maintain their form and structure. That is death, the only known death, and that science seeks to interpret. But those who, greatly presuming, looking only on the material surface of reality, and thus profoundly ignorant, would infer from the bodily disintegration which we call death that nothing beyond remains, have yet to pass through science or "knowledge" to wisdom, which knows, as Socrates said, *what it does not know.* "Where shall we bury you?" they asked him, before the executioner came. "Where you will," was the reply, which has survived the ages, and will survive infinite ages more; "*if you can catch me!*"

A DEATH-STRUGGLE BETWEEN TWO PLANTS

This remarkable photograph of a section of clover stem, taken through a microscope, shows how the common dodder lives as a parasite on another plant. The seed germinates in the ground, and the dodder then starts out in search of a victim. As soon as it touches another living plant it coils its thread-like stems around it, putting out a series of little roots that eat their way into the plant as shown in this picture. Then the dodder's original root dies, and it lives entirely upon its victim until it strangles it. Dodder is very destructive in English gardens, and in Germany destroys whole fields of clover.

MOTHER EARTH'S CUPBOARD

The Storehouse in which Food for Plant Life is Kept and How it is Constantly Replenished

THE SOIL PACKED WITH THE SOURCE OF LIFE

Having gained the knowledge of what the soil is made of, and how it is made, and having realised that from this soil comes almost everything we use, the thought at once comes to us that the soil must inevitably be a veritable storehouse of food for millions of living things. In spite of the fact that the earth is usually regarded as a mass of inert matter, it is true that the soil we so carelessly trample down is full of life.

This question of the nutrition of plant life may very well serve as a basis for a classification of plants themselves, according to their methods of life. Such an arrangement gives us four groups of plants -water plants, stone plants, ordinary land plants, and plants which live upon others. Doubtless these four groups of plants have intermediate connecting links, but it is convenient to regard them as distinct.

In the first place, we have the aquatic plants, obtaining their food for the most part, if not altogether, from the water in which they live, this being done whether the plant is fixed by submerged roots or whether it be free in the water. Some plants there are which obtain their food from the water and from the atmosphere as well, should the former subside.

In the second group, which is a small one, we have those mosses and lichens which are found closely adhering to the surface of stones. These plants must necessarily derive their sustenance directly from the air; and a characteristic of such plants is that they are able to resist dryness for a very long period. Plants living on stones with their roots penetrating crevices are, of course, not of this class, but are land plants.

By far the great majority of plants belong to the land group, deriving their nourishment—whether fluid, such as water, or mineral constituents that are held in solution—from the soil itself.

Since it is usual for a plant to be fixed to one spot, unable to move about with the freedom of an animal in search of food, it is obvious that sooner or later the plant must exhaust the supply of nourishment available in the immediate neighbourhood of its roots. When this is being done, we can observe these roots reaching out farther and farther from the central stem. Even then, were it not for the combination of natural processes which are called the battle of the soil, any given plant would exhaust the stock of food in its immediate vicinity. It is, however, also true that, within certain limits, land plants do move with a view to secure nutrition, and these movements must be studied.

How do plants absorb their foodstuffs? Plants all consist of one or more cells, and in the majority of cases the plant cell has an envelope enclosing the cell protoplasm. It is necessary that all food must find its way through this envelope before it can be built up by, and into, the protoplasm within. This is a necessary conception which forces us to the view that the envelopes of these cells are so made that food particles can pass inwards through them, and that other matter can pass outwards without injury to the cell itself. Doubtless the openings in the cell-wall, which allow of this exchange, are infinitesimally small, but exist they must. The whole process has been aptly compared to that of the passage of particles through a fine sieve, the wall of the cell corresponding to the meshwork of the sieve. The process by which the fluids pass from one side to the other of such a cell membrane is termed *osmosis*, and is of importance in forming a conception of what goes on in plant nutrition. Moreover, we must conceive

that the cell protoplasm is able to absorb and select the soils of different sorts lying in the surrounding earth, and to go on doing so until the requirements of the cell are met.

This is chiefly brought about by the affinity for water that the cell substance possesses. It is a chemical affinity. Another chemical affinity accounts for the diffusion outward from the cell to the soil. In this way there takes place, as far as one can imagine, the process of interaction between different living cells which results in plant nutrition.

A MISTLETOE PARASITE GROWING ON AN APPLE-TREE

A parasite plant is a plant that lives upon others, and the mistletoe which lives generally on apple-trees, is one of the most familiar examples

Next comes the question: What are the actual foods thus absorbed? They may be placed in four groups—gases, salts, water, and organic matter, all of which the soil supplies to plant life, and the sources of which we have already seen.

The gases which claim our attention are carbon dioxide, nitrogen, and ammonia. Carbonic acid is one of the most important sources of plant nutrition. This does not occur as such in the atmosphere which contains the gas carbon dioxide, but the carbonic acid is formed when the carbon dioxide is absorbed by the water. The cells of plants obtain their carbonic acid from both water and air; and it is an interesting fact that this gas will penetrate through a cell membrane saturated with water more easily than will the oxygen or the nitrogen which is also in the air.

Passing through the cell membrane, carbon dioxide is converted into the acid, and in that form reaches the protoplasm. The quantity of carbonic acid thus absorbed varies according to the amount of nourishment required, and this in turn varies particularly with the time of the day. All green plants require carbon during daylight, and as soon as the carbonic acid reaches the cell sap it comes under the action of sunlight, and undergoes chemical processes which result in the formation of those important substances known as carbo-hydrates. In this process oxygen is set free and sent out into the surrounding medium, either air or water. This constitutes one of the most valuable examples of the constant interchange of plant life and animal life. The result is a gain of carbon to the plant, which is the element particularly required, and the process goes on so long as the cells in the plant which contain the green colouring matter are exposed to the action of daylight. In the process are also produced, as the result of the decomposition, sugar, starch, and other organic compounds.

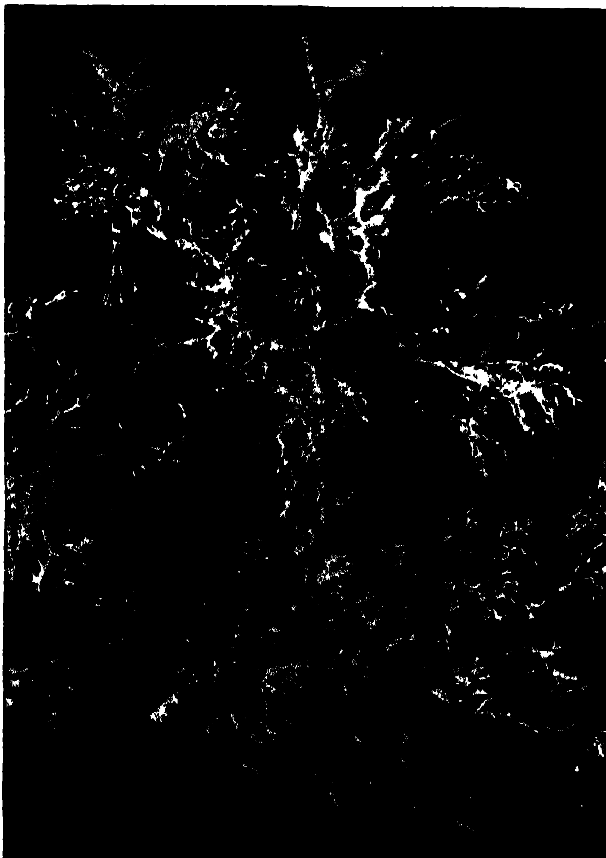
In the case of a submerged plant the carbonic acid required is obtained from the water, which always contains more or less of that compound, but the absorption can take place only by means of those cells which are actually exposed to the water itself. Some of the carbonic acid is also absorbed in the form of carbonates. Plants which live on stones get their carbonic acid from the watery vapour in the atmosphere, and partly by direct absorption of carbon dioxide from the air. Land plants, on the other hand, obtain their requirements of large supplies of carbon almost entirely from the carbon dioxide in the air around them. No plant is known to take up carbon dioxide or carbonic acid from the earth.

We now come to the nitrogen required by plants, and this food is mainly supplied

from the nitrates and compounds of ammonia which are absorbed from the soil. But, in addition, the ammonia and nitric acid in the atmosphere supply a little. It is the decomposition of dead organic bodies which furnishes the nitric acid in the soil. And this is treated in somewhat the same way as the carbonic acid, forming other compounds.

Ammonia, too, has a very similar relationship to plant life as have carbon dioxide and nitric acid. It occurs in very small quantities in the air, and in water in which organic bodies are decomposing. But the principal source for the nutrition of plants is the decomposition of dead bodies in the soil. Water plants are obviously limited in the power of acquiring ammonia, as also are stone plants. The water plant obtains its ammonia from decomposed organic matter in the water; the plant living on stone is restricted to the ammonia in the air. But land plants, in addition to the ammonia they derive from the soil, can also utilise that in the atmosphere.

Next with regard to the salts required as food. A knowledge of what these salts are is obtained by burning the plants, collecting the ash which remains, and subjecting it to analysis. The weight of this ash is usually not more than one or two per cent. of the original plant. The proportion is greatest in water plants and smallest in fungi and mosses. But, however small the proportion may be, these nutrient salts are an essential element in the food of the plant. If these elements are entirely withheld the plant withers and dies. Experiments have been made with many salts with a view to ascertaining which of these chemical compounds are essential and which are not, and this is done by adding the salt to the water which is supplied to the plant roots. The essential salts are those entering into the composition of the cell protoplasm, and which are used during the process of growth. They are the salts of phosphorus, potassium, calcium, and magnesium, together with those of iron for green plants, and sodium, iodine, and chlorine for water plants. Silicon is also an important element.



THE LICHEN PLANT THAT WILL GROW ON A STONE
Stone plants, of which lichen is a familiar example, derive their sustenance from the air. Lichen was one of the first things to grow on the earth.

All these elements, in order to be utilised as food, have to be transformed first into salts, and can only reach the interior of the plant cells by passing through the membrane in watery solution. In this way we reach the conclusion that the important food salts of plants are the soluble sulphates, phosphates, nitrates, and chlorides of calcium, magnesium, potassium, and iron. Whether the element is contained in one or another of those salts does not appear to be a matter of great importance; that is to say, so long as the plant obtains the phosphorus it needs, the result is equally satisfactory, whether it be in the form of potassium phosphate or sodium phosphate. Sulphur is essential for the manufacture of proteids. Potassium takes a part in the formation of starch. Calcium is required because it assists in bringing the sulphur. Iron seems to play a part in the production of the green colouring matter, as has been proved by experiments on artificial growths in which plants with no iron turned out white instead of green, the addition of the iron element rectifying this. Silicon plays a different part. This element is abundant in the ash

of many plants and is particularly concerned in producing stiff hairs and so forth which form protective appliances. Most of these elements are therefore essential to assist the plant in carrying out the chemical processes going on within it, all of which are necessary for its maintenance and growth.

ABSORPTION HAIRS ON THE TIP OF A BARLEY ROOT

All these various salts are present in the soil and can be utilised by the plant, showing that the soil is a veritable storehouse of food. The salts are produced partly from the weathering of rocks, partly from the water in the soil which contains them in solution, partly from the water of springs, rivers, ponds and sea water, and partly from the decomposition of dead animals and plants, the decay leaving the mineral constituents behind.

In the scheme of Nature it is found that those salts most required for plant life and successful vegetation are those which are most widely distributed over the earth. Sulphates of calcium and magnesium and salts of iron and potassium have a universal distribution in both soil and water. They are not, however, by any means absorbed by the plants in proportion to their abundance in any given soil, but only in response to the actual requirements of the plant.

So far we have been considering the absorption of nutritious salts by land plants or stone plants, but there remains the consideration of these points in connection with water plants. Here it must be remembered that quite a number of plants which live in water have their roots fixed at the bottom of the water, the stems only being submerged, while the leaves are exposed to the air, just as in the case of other plants.

WHY A ROOT GROWS DOWNWARDS

A r t gr w d w w r l t l use it is dr v l y it w ight but le us it l r unishm nt The f u l the tip f r is l y sl h r t l rls s alt fr m th i t jj ar t r s l ctu a l l v m th e rth

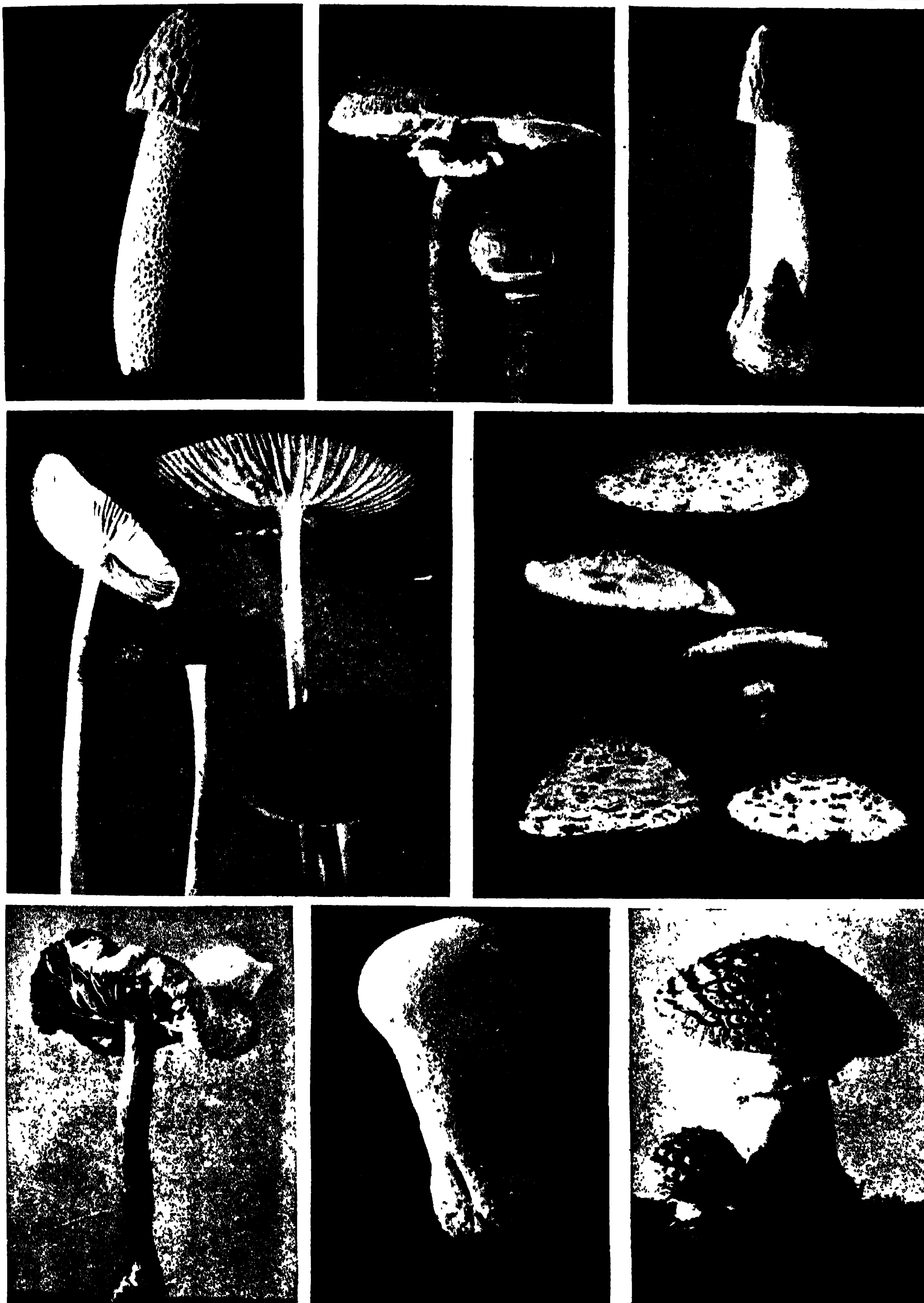
In such cases, of course, the method of food absorption is similar to that in ordinary plants, as far as the roots and the leaves are concerned; that is to say, the leaves absorb the carbonic acid directly from the atmosphere, and the roots absorb salts from the soil under the water. Plants of this kind should be regarded in this respect as land plants. They are really marshy plants, and they include such familiar species as rushes and water lilies. As a matter of fact, if these plants are entirely submerged for a considerable time they die.

The true water plants, however, which pass their entire life in a submerged condition, obtain their food directly from the water in which they live. If they are taken out and exposed to dry air they die just as the marshy plants do if submerged. Many of them die very quickly, simply because the water in their cells escapes, so that the whole plant dries up. The greatest resistance to this is seen in the marine aquatic plants, as can be observed in the seaweeds along

THE HAIRS ON THE TIP OF A ROOT BY WHICH A PLANT ABSORBS WATER

The two microscopic photographs on this page show the hairs by which the plant absorbs its salts from the soil and the water. The hairs on the root require moisture, and a root, instead of turning downwards as gravity would suggest, will follow the direction of moisture

A STRANGE KIND OF PLANT LIFE

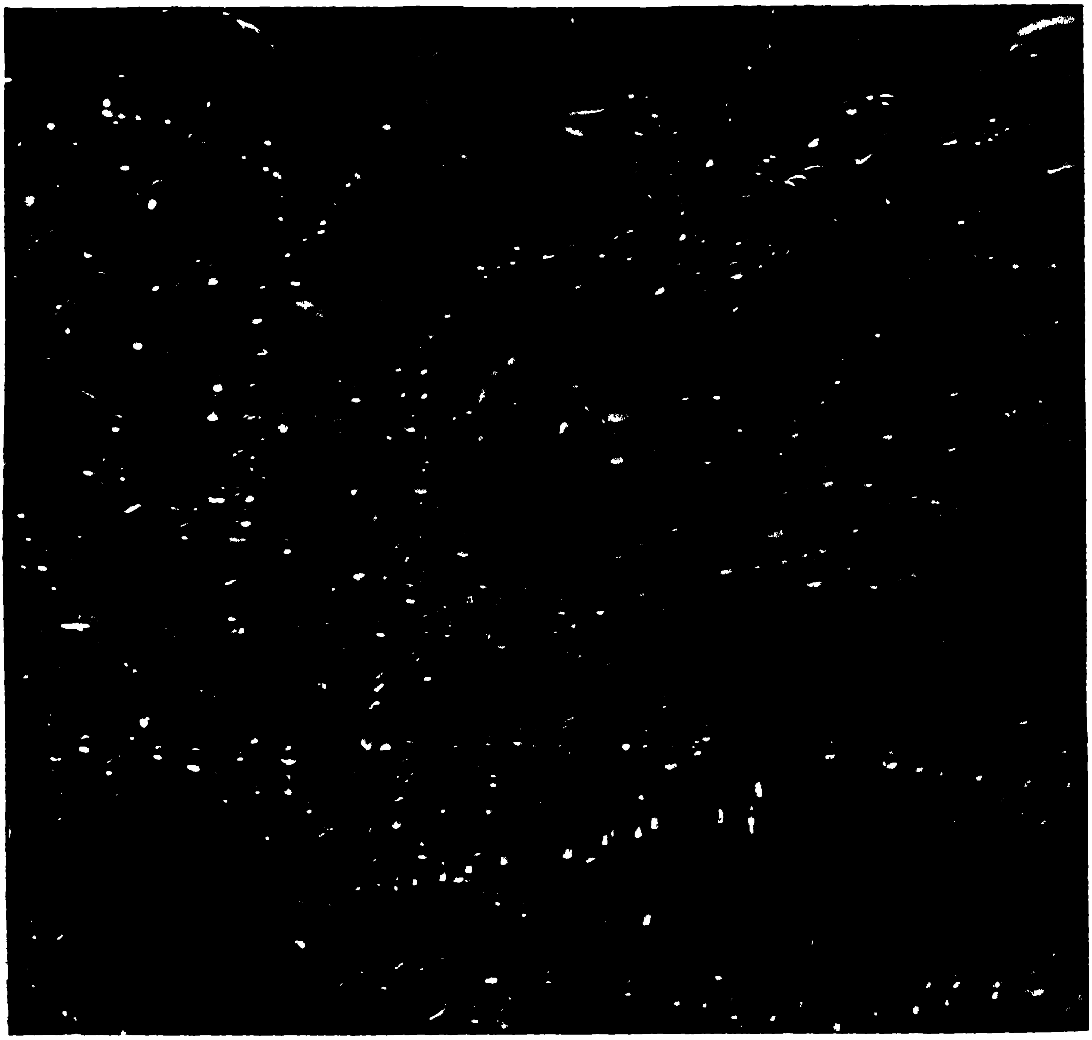


Funguses are in some ways the strangest of all plants. They include the moulds and mildew that form on foods and elsewhere, but the higher kinds of fungus are the mushrooms and toadstools, some familiar British examples of which are given on this page.

the sea-shore, which are regularly left high and dry at low tide. These plants can withstand high temperatures and great dryness on account of the thickness of the outer layers of their foliage, which enables them to hold sufficient water until they are again submerged with the next tide. The majority of true water plants are fixed to some rock or stone under water.

In the marine plants sodium and iodine form important elements of the food, and great quantities of salts are absorbed; in fact, it is found that very few water plants occur in extremely fresh water. The more salt in the water, the more plants there are likely to be. Running streams, therefore, are not prolific sources of plant life. Such water is always deficient in salts as compared with the water of pools or rocks. Possibly, too, the motion of the water presents some mechanical difficulties in the absorption of the salts.

Coming now to the stone plants, it might be supposed that they obtain their nutritive salts directly from the stones and rocks on which they grow, but this is not so. The stones and rocks to which moss and lichen attach themselves do not serve the function of soil, but are merely a means of attachment. Like ordinary land plants, the stone plants obtain their salts from the atmosphere, and these salts are precipitated upon the plants in the tiniest particles of dust.



DEW DROPS—THE BEAUTIFUL WAY IN WHICH THE AIR GIVES WATER TO THE EARTH

In the ordinary land plants the salts in the soil are absorbed by hairs on the root of the plant, special cells, or protoplasts, exerting a powerful attraction upon the foodstuffs required. It is a sort of suction process on the part of the cells in contact with the soil, dependent upon chemical

LAND PLANTS AND WATER PLANTS

THE FOXGLOVE—A TYPICAL PLANT OF THE GREAT LAND GROUP FINDING ITS FOOD IN THE SOIL

FIELD OF WATERCRESS—A STRIKING PHOTOGRAPH OF PLANT LIFE GROWING IN WATER

Aquatic plants obtain their food for the most part from the water in which they live, this being done whether the plant is fixed by submerged roots or whether it is free in the water By far the great majority of plants belong to the land group, however, deriving their food from the soil.

affinities. We have already seen that every particle of earth in the soil has a watery film around it, and also that the wall of the cell, as well as the interior, is saturated with water. It is along this continuous waterway that the foods in the soil pass in.

Special cells in land plants are concerned with this absorption of salts, and these cells are in very close contact with the minute soil particles. They are specially found in connection with the tips of roots, and constitute what we have called root hairs. These absorptive organs are developed in land plants wherever the nutritive matter is found, wherever the root finds moisture and salts.

The Delicate Little Instruments by Which the Root Takes in Food

Everyone knows that roots grow downwards, but the reason for this downward growth is not merely the weight of the roots. It is a vital process on their part. They are in search of food. The absorption cells do not appear in connection with roots until the roots have penetrated into the region of the soil.

These root hairs can only perform their work when the soil is moist; and we find that, whenever the choice is offered of a moist or dry soil, they invariably select the moist. Thus, instead of a root growing straight downwards, as gravity would suggest, it will turn in one direction or the other according to the presence or absence of moisture. These root hairs are found always just behind the tip of the root; and as the root grows longer and longer, new hairs are produced, always at the same relative distance from the tip. The more delicate the foliage of a plant, the longer and more numerous are the root hairs. This is because the delicate foliage allows the more ready escape of moisture from the plant, which must therefore absorb more water to maintain the balance. On the other hand, evergreen plants, in which the stiff structure of the leaves causes very slow conduction of water from the roots, have less luxuriant hairs.

The Universal Demand of all Plant Life for Water

It will be seen that, of all the food contained in the soil, water is the most important. Water is a necessity of all growth in all plants, as in all living creatures. It has to be incorporated in the building up of the sugar, starch, cellulose, fats, acids, and proteids, and is, indeed, as indispensable from its own point of view as is the carbon dioxide found in the air. But not only is it indispensable in itself, it is also the only medium by means of which the mineral salts of land plants, water plants, and stone plants can reach the interior of the plants. It also carries the organic compounds which feed parasitic plants.

The importance of water to the life of a plant is twofold—it is an essential food material, and an indispensable medium for the transport of other foods found in the soil. It is on this account that the demand for water on the part of all plants is great and universal. Its absorption is simplest in the water plants, where it passes into the plant with other food materials. In the land plants it is sucked up by means of absorption cells in the root hairs, along with the food salts from the layer of soil in which this portion of the root lies.

The food in the soil which is available for the use of plant life is either gaseous, in the form of salts, or water. There remains the fourth kind of plant food to be considered—organic matter, which is produced by the decay of the tissues of both plants and animals. Wherever the dead bodies of plants or animals are left to decay, there we find great numbers of fungus plants developing. With these we associate the unpleasant smell we call mouldy, which is always found in such situations.

The Food which is Always Being Renewed by the Plants that Consume It

Besides the fungus, quite a number of other plants absorb organic compounds from decaying products for the purposes of food. It is not always possible to tell from the composition of soil whether the plants in it obtain their organic matter from this source or from the air. It is possible for plants which are rooted in dead organic matter to take nothing from it but the inorganic mineral salts. It must be remembered, also, that the plants growing in sand or loam in which there is no humus may obtain organic matter from the water filtering through this soil, which brings organic matter from a distance.

All cold mountain water contains minute traces of organic compounds; and thus it is that even clear mountain springs contain sufficient organic material to provide food for fungi. This organic matter comes from the upper strata, which contain more or less humus and supplies the water percolating through it with this food. Rain and snow acting upon the decaying vegetable matter on the surface of the soil in forests absorb it and carry it down with the loam beneath. The plants whose roots are

spreading in this deep layer of earth are thus able to obtain their organic food, as well as their mineral foods, by means of the water.

The supply of all these various kinds of food in the soil is constantly being renewed by the living plants and animals which consume it. Thus, wherever vegetation is left to itself, the very materials of all the food salts which the vegetation has extracted from the soil will in due time accumulate in the upper layers of the soil.

How the Fallen Leaves Give Back their Vital Power to the Soil

Every plant gathers together the substance it requires for its own nutrition, and the longer it lives the greater the amount it stores up within itself. When such a plant dies, the elements it abstracted from the atmosphere return to the atmosphere during the process of decay. The elements which it derived from the deeper layers of the soil do not return, however, to their original depths, but remain on the surface, or near it.

Every autumn the fall of the leaves adds to the accumulation of the nutritious salts in the topmost layers of the soil.

It is, however, the mineral salts alone of the essential constituents of the plant which remain unaltered after death. The carbon and nitrogen, which are built up into the organic constituents of the plant, and make the fundamental mass of plant structures, do not, after the plant's death, remain behind in a form in which they can be utilised for other plants. All the carbohydrates are soon split up in the late autumn into the same simple compounds from which they were elaborately constructed in the summer. The more freely a dead plant is exposed to the air, the more quickly does this disintegration take place.

The Apparent Destruction and Decay from Which New Life Arises

Provided the atmosphere on the surface of the soil does not fall below freezing-point or thereabouts, all the dead leaves and branches and tree-trunks, as well as the dead roots in the upper soil, undergo processes of decomposition in the presence of moisture, and so return their organic elements to add to the supply of food in the soil. If the accumulation of dead vegetable matter in any given point is very abundant we have a quantity of vegetable mould formed. The drier the general conditions, the less quickly and thoroughly decomposition occurs.

The actual agents concerned in the process of restoring food elements to the soil are, as we have seen, the microbes, the minute organisms which carry on their work in the presence of moisture and within certain limits of temperature. Wherever vegetation flourishes to perfection these organisms occur in great quantities. In their absence no decomposition or putrefaction can take place. Similar processes of decomposition can be brought about by mould and fungus. By their means the organic compounds in dead plants are restored to the air in the shape of water, carbonic acid, ammonia, and nitric acid. Thus the destruction of dead plant life is a means of returning to the atmosphere the compounds taken from it when the plant was alive, and the carbon and the nitrogen are returned in such a form that they can once more be utilised by other living plants for food.

We are confronted, therefore, with the thought that the decay of dead plants and animals is absolutely necessary for the production and maintenance of the supply of the vast number of foodstuffs we find in the soil. It is not too much to say that the continuation of plant life and of all animate nature is dependent upon this process of putrefaction, which many of us are accustomed to regard as an undesirable thing.

How the Earth is Like the Widow's Cruse Which was Always Filled

But for this an immense quantity of carbon and nitrogen would every year remain locked up in the bodies of dead plants, where it would be unavailable for the food of the living; and if this were to go on for a sufficiently long period life would become impossible, and our globe would be one vast cemetery. The ultimate result of this putrefaction is the return to the atmosphere of the elements required for plant life, and the return to the soil of the mineral foods which once more become available. The putrefactive process, in a word, is a process of purification. The universal occurrence of the minute living creatures which carry out the work not only maintains the necessary supply of the various foods in the soil and the air, but keeps our rivers and ponds and air and earth in the only condition in which it would be possible for life to be maintained.

We have, therefore, to regard the soil, so far from being lifeless, as packed with life, containing food which is in a constant state of formation and decomposition. We are to regard it, indeed, as a storehouse for the food of millions of living things, in which there is taking place continuously an infinite number of processes that render life possible. What these processes are, what it is that happens in the soil, we must next consider.

THE TERRIBLE KING OF BEASTS—HOW THE LION SPRINGS PITILESSLY UPON ITS PREY

In securing his food, the lion has recourse to cunning, stalking skilfully, and displaying marked cleverness in taking advantage of the least cover. When near enough to trust to his speed for the final dash, he hurls himself at his prey, grips the victim with his forepaws, and inflicts a crushing bite upon the back of the neck. A bite at the throat follows, to secure a deep draught of blood, not to kill, the first wound usually depriving the victim of all power to resist.

THE ANIMALS OF TERROR

Leading Members of the Great Cat Family—Life and Habits of Lions, Tigers, Leopards, Jaguars, Cheetahs.

THE FEARFUL BEASTS THAT FEAR ONLY MAN

Madame de Staël declared that the more she knew of men the more she admired dogs. The student of Nature, on the other hand, is impelled to admit that the more he knows of the flesh-eating animals, the great carnivores, the more he admires man.

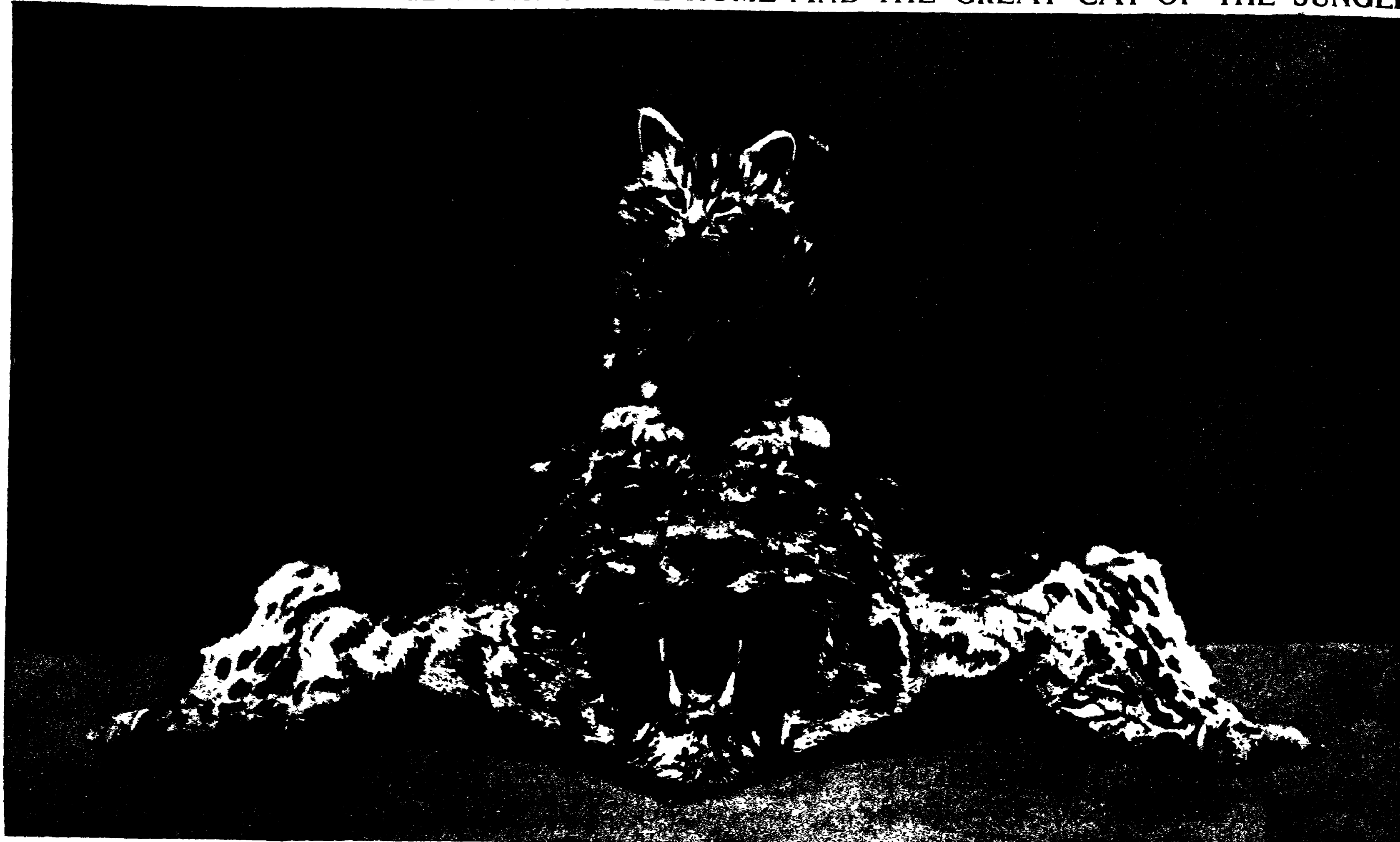
The carnivora appeared on earth ages before man emerged, and, attaining to great physical power, to the possession of superb weapons of offence and defence, they became the most terrific instruments of destruction in animate Nature. And such they have remained. By every law of probability the human family should have disappeared entirely before them. The carnivora have lived through the ages entirely by slaughter. They are in the world for carnage. They die when they can no longer kill. If all the carnivorous animals of the world should this day be seized with a lasting repugnance to taking life, they would become extinct. Only gradually, through a long period of time, could they adapt themselves to a different diet. They are so constituted that they can live only on the flesh and blood of other animals.

Yet in the presence of this vast devastating host, ranging almost the entire world, man, by his cunning and courage, has achieved supremacy. He still pays heavy toll in human life to these ferocious captains of the wilds; never a day passes in which somebody in the British Empire is not killed and eaten. But the victory is as a whole with man. The lives now lost are as those sacrificed to snipers through whose country a victorious army is marching. We may consider ourselves spectators of the closing phases of this contest, ages old, between man and the beasts of prey. The time must come when the last free lion and tiger and leopard will have to be slain. Civilised man cannot live in company with the great cats. The man-eaters are bound to go, as surely doomed as were the wolves which ravaged English homesteads long ago. In the meantime the battle is being waged; and in Africa, Asia, and America the great cats are making as fierce a fight against the conquering host of men as they have ever done.

The scene is the same, though its boundaries are constantly being narrowed down before the steady advance of civilisation. Man now has firearms instead of the primitive weapons with which his ancestors fought, but to-day the unarmed man is as helpless before lion or tiger or jaguar as were the earliest men. Indeed, perhaps he is a little more powerless, for civilisation has made him forget how to fight with natural weapons. In contests such as these the conditions are unaltered from those in which the first puny men matched themselves against the ferocity and strength of the flesh-eaters. The death-roll is grievously heavy, but it is perhaps strange that it is not heavier still. In the last resort the great cats do not fear man. In the abstract they do. If they reason it out at all, they may possibly associate his presence with the presence of their greatest terror—fire. They have certainly learned to discriminate between an armed man and one unarmed; and this is nowhere more conspicuous than in India, where the tiger snaps up a native, yet skulks—in the daytime, at any rate—from the man behind a gun.

With all his insensate savagery, the lion, now that one of his great provinces has been wrested from him, commands a sort of sympathy. India has become the grave of almost all the race of lions that peopled its jungles and its stony plains. The animal has been practically exterminated throughout the country; a few, however, are now carefully preserved in that portion of Kathiawar known as the Gir Forest, and

TWO COUSINS—THE LITTLE TIGER OF THE HOME AND THE GREAT CAT OF THE JUNGLE



The domestic cat is merely a lesser tiger; the tiger is one of the largest cats. This photograph of a kitten perched on the head of a leopard shows the close resemblance between these vastly different members of the same family.

Some of the photographs in these pages are by Mr. W. P. D[illegible] and by Mr. Gambier Bolton, Mr. Bolton's being reproduced by permission of the Autotype Fine Art Company

it was stated a short while ago that even there only half a dozen still remained. But there remains a great part of Africa, from Cape Colony to Abyssinia and Algeria; and in Asia the lion claims Southern Persia and Mesopotamia for its range. We still call it the "king of beasts," for, while it lacks the impossibly noble qualities with which man was once wont to invest it, there is no other animal that can be exalted in its place.

No other beast can compare with the lion for splendour of appearance. This applies, of course, to the great maned lion, which, by the way, is seen at its best in captivity. It would seem as if life in the cage encouraged the growth of hair, so that we get a false notion, from the appearance of the menagerie lion, of the figure that he presents in the wilds. But even in its natural state the appearance of the lion is impressive enough. The mane and ruff serve not merely as adornment: they constitute an armour to defend the neck and throat of the lion in battle with other carnivores.

The Battles Between the Lion and the Tiger which may have Driven the Lion from India

This protection must have been necessary for the Indian lion in such battles as he fought with the tiger, for, though the lion looks a bigger and stronger animal than the tiger, the tiger has the advantage in jaws and claws; and such evidence as we have of battles between the animals goes to prove that the tiger is generally victorious in combat. Indeed, Major Alexander holds that the disappearance of the lion from India is in part due to tigers, which have either driven away or killed such lions as survived the onslaughts of man.

In making this comparison between the two animals it should be remembered, however, that it is in Africa, from which continent the tiger is absent, that the lion reaches its maximum strength and size. Even the African lion, however, would stand but small chance with the largest of the tigers--the Siberian variety. It is a little difficult to arrive at any definite knowledge as to the actual bulk of either animal, however, for weight has to be reckoned and proportions measured in the wilds where the kill takes place. Still it is within the mark to say that lions weighing over 500lb., and measuring ten feet from the muzzle to the tip of the tail, are not uncommon.

One feature the king of beasts possesses unchallenged—his voice. Livingstone was one of a few men who have declared that the roar of the lion is indistinguishable from the note of an ostrich, but there are men who cannot tell the melody of the British National Anthem from "Yankee Doodle." When lions roar in chorus, as they are accustomed to do when rival troops approach the same water-hole, the very ground is shaken; and the effect upon a listener, lying chilled and apprehensive in a veldt camp, is more impressive than anything else the big-game hunter knows. The fact that the lion, like all the other carnivora, is a night animal, and roars only when man is abed, makes his solemn, deep-chested notes the more awe-inspiring.

The Terrible Way in which the Lion Attacks its Victims

The food of the lion varies with his habitat. In the oak forests of Persia, the wild pigs furnish an abundant diet; in Africa, the zebra, the hartebeest, the giraffe, the antelope, and, more rarely, the buffalo, is the staple food. The teeth are the lethal weapons, not the mighty claws. It is commonly supposed that the paws are used to kill, but as a fact they are only the gripping instruments. Men have been killed, no doubt, by a blow in this manner, but not necessarily by design of the lion. As a cat claws at a mouse which moves, not to kill, but merely to retain it, so the lion strikes with his sledge-hammer limb at head or leg or hand which his victim moves. In attacking animals he does not, as a rule, spring boldly upon his victims, as pictures commonly represent. He rears himself into an almost upright position, and, while standing on his hind legs, grips the animal with his forepaws, and inflicts a fatal bite at the back of the neck. This he follows with a deep bite in the throat, apparently in order to drink of the victim's blood, as the bite is not necessary to kill, the blow from the mighty paws having destroyed all power of resistance in the unhappy victim.

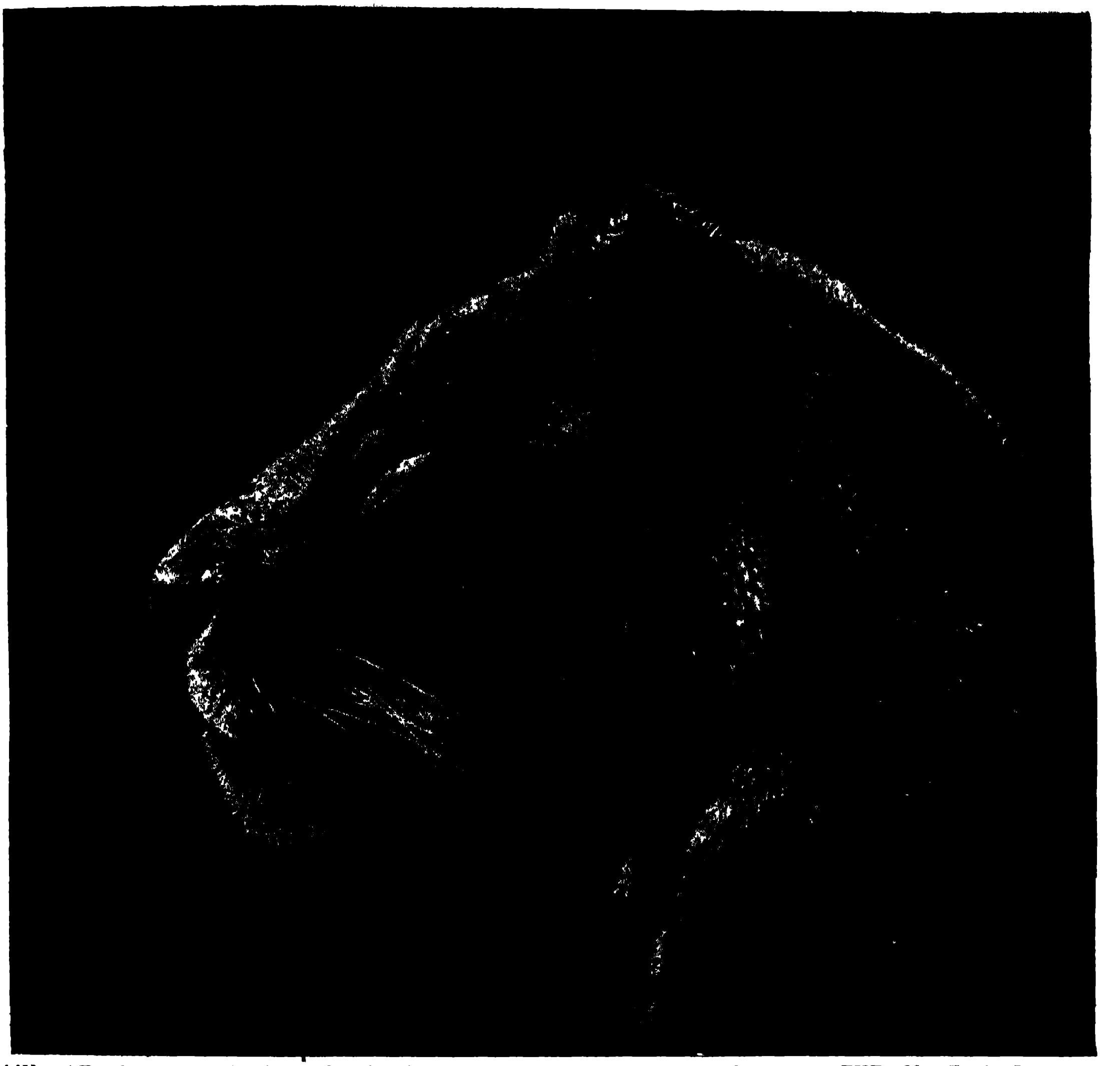
The Lion that Roared for Hours Outside Dr. Livingstone's Camp and Dared not Enter

The fear of man which the great cats commonly experience is observable in the day rather than night. The contempt which a lion shows for man after sundown suggests that the camp-fire may be the actual cause of his fear. One lion roared for two hours close to Livingstone's camp, but could not muster up courage to pass into the lighted circle. Even the camp-fire fails at times, however, to stop the determined man-eater. How the lion takes to man-killing it is always difficult to say. The general supposition is that the animal resorts to the quest of man only when his speed and strength are waning, so that

THE HANDSOME HEAD OF THE GREAT MANED LION, WITH WHICH NO OTHER ANIMAL CAN COMPARE FOR SPLENDOUR OF APPEARANCE.

fleeter game passes beyond his reach. That, however, was not the fact concerning the man-slayers at Tsavo, whose depredations actually brought the building of the Uganda Railway to a halt. These animals were neither old nor decrepit; they did not lack other food, for large flocks of sheep and goats, together with other animals, surrounded the works. But night after night one or both of the brutes crept silently into the camp, avoided all traps, and eluded watchers lying in wait to receive them with guns. And at every visit a man disappeared. Colonel J. H. Patterson, who was in command, and to whom it fell in the end to slay the lions, has told the whole story in his book, "The Man-Eaters of Tsavo," which should be read by all interested in the natural history of the lion.

These animals certainly displayed greater skill and rapacity than Livingstone would admit as the attributes of the lion, but the varied experiences and observations of travellers compel us to believe that lions differ in character as much as dogs and horses. While some are stupid and cowardly, others display considerable cunning and invincible boldness. The man-slayers of Tsavo turned the tables on their hunters, and so did another fierce brute whom three men set out to kill at Kiu, when the railway was being built in British East Africa. The hunters ran their sleeping-carriage into a siding, and sat up one night to watch and wait. The night was dark, with little moon, and about midnight one of the party, an Englishman, remarked upon the brightness of the "fireflies" near the



THE AFRICAN LIONESS, WHICH HAS NO MANE, AND IS PROBABLY THE MOST FEROCIOUS BEAST ON THE FACE OF THE EARTH.

carriage, and noted also that a rat repeatedly crossed and recrossed a spot where a steel rail glinted in the moonlight. But the "fire-flies" were the eyes of a lion, and the "rat" was its tail dragging across the rail as the animal moved slowly to and fro. The lion was stalking its hunters. Towards morning the three men dropped off to sleep, the Englishman sitting upright with his back to an open window. Suddenly the lion sprang into the carriage, seized the Englishman, worried him in the presence of his horrified companions, then leapt out through the opposite window, carrying him in its mouth.

As grim an experience was that of Mr. Ernest Brockman, a traveller who found himself near Kota-Kota in British Central Africa. Here a lion broke into his tent at night, seized him by the shoulder, dragged him out of bed, and then, grasping him by the groin, carried him only thirty yards away, and deposited him under a tree. Then, though natives were firing right and left, and torches were gleaming in all directions, the brute lay down by its victim, and drank his blood. Each time the man moved, the lion bit him or pinned him afresh with his paw. But he did not yet seek to kill; he bit only in order that he might drink blood, and he continued at his awful work long enough to enable a friend of the victim to get up and shoot the lion dead. Mr. Brockman was rescued in a terrible plight, with twenty-one bad wounds, but he recovered to tell the tale.

The courage of the lion, never in dispute when the animal is brought to bay, becomes a sort of frenzy when he is wounded. The spring of 1911 brought a tragic instance of

this, involving the terrible death of Mr. George Grey, brother of Sir Edward Grey. Sir Alfred Pease's ostrich farm at Athi River had for some time been harried by lions. A hunt was organised, two big lions were driven from their hiding-place, and one of these turned to charge. Mr. Grey dismounted and fired a shot into the animal's shoulder. This did not stop him, so Mr. Grey fired again, the second shot smashing two of the animal's fangs and seriously injuring his lower jaw. But the lion charged home, knocked his victim down, and mauled him horribly. The other members of the party now rode up, and the lion turned to face them. A third bullet was put through his ribs, but he returned to Mr. Grey, and, as an eye-witness said, "worried him just as a dog worries a rat."

A Dying Man Without Pain in the Grip of a Lion

A fourth shot was necessary to finish the monster. Mr. Grey was frightfully mauled, yet he seems to have felt no pain, for he was perfectly calm and cool, and able to advise his horrified friends how best to handle his lacerated body. Unhappily, however, the after-effects of his injuries were so serious as to cause death.

It is sometimes asserted that the lion is less wantonly cruel than the tiger, and that it will not kill for killing's sake. There is little in the theory. Lions are as savage in instinct as the pet cat which, after being fed with delicacies, will go into the garden and kill, for sheer lust of slaughter, birds which it makes no attempt to eat. Mr. J. G. Millais encountered a lion which at various times had eaten half a dozen native women. It was neither old nor feeble; it was a ten-foot lion, in the prime of its vigour and speed. It visited his camp one night, and struck down a donkey within five yards of his camp-fire. Two other donkeys broke away in terror. The lion left his first kill, and pursued them, slaying first one and then the other. It ate the third.

How the Tiger Interferes with the Supply of Coffee

The tiger is more destructive of human life than any other animal in India, in spite of the fact that hundreds upon hundreds of tigers are slain there every year. But while the tiger is the animal for which India is notorious, its range is by no means limited to that country. It flourishes throughout a great part of Asia and its islands; and in places such as Java and Sumatra it is sufficiently numerous to affect the commerce of the world. So serious are its ravages at times that the supply of coffee is periodically curtailed owing to the tigers infesting the route from the interior to the coast. In India, however, its depredations are such as to wipe out entire villages. Not that it kills every one of the inhabitants; but it kills so many that the remainder dare no longer stay. Many deserted villages are to be found whose populations have been thus in part destroyed, in part driven away by these terrible beasts. We are all familiar with the story of the tiger's misdoings in India, for Government returns are issued each year telling the dismal story. These show that the deaths caused by tigers was 909 in 1908, 896 in 1909, and 853 in 1910. In the same period nearly 5000 tigers have been killed. Seeing that tigers claim a great share of the 90,000 cattle destroyed by wild animals in India every year, it is not to be disputed that our Eastern fellow-citizens pay dearly for their unwilling hospitality to this ferocious animal.

The extent of the casualty list seems, on the face of it, to challenge the accuracy of the suggestion that the tiger shares the fear of man common to most animals.

The Terror of Life in the Country Haunted by Tigers

But, after all, the man-eater is the exception among lions and tigers. The tiger is responsible for more deaths than the lion, but the population of India is extremely dense; the natives are timorous and superstitious, and hopelessly fatalistic.

It is among the natives that the tiger finds his victims; he distinguishes readily between the defenceless Hindu and the armed man. The native who tends cattle in tiger-haunted country sees many of his charges disappear before he himself is attacked. Then, some day, something unusual occurs. Either he provokes the tiger to rage by attempting to baulk it of its prey, or the tiger is indisposed to tackle a bullock. He attacks the man, and then the worst has happened. There seems no doubt, as concerning the tiger, that, "once a man-eater, always a man-eater" is the rule. Man, so long dreaded or avoided, proves even more vulnerable than the cattle, and man becomes the diet of that tiger. Thus we find that the human victims of a single tiger often run to scores.

There is very little difference between the habits of the lion and the tiger, and very little difference in structure. The distinction is chiefly on the surface. The tiger is striped, the lion is not. The tiger is not maned, and he lacks that tuft of hair at the end of the tail which distinguishes his

CATS OF THE OLD WORLD AND THE NEW

E LITTLE-KNOWN SNOW LEOPARD, WHICH HAUNTS THE MOUNTAINS OF CENTRAL ASIA

THE PUMA, THE GREAT AMERICAN CAT WHICH DEVOURS CATTLE AND HORSES

The snow leopard, or ounce, is a mountain haunting cat of Central Asia. Owing to the inaccessibility of its home, the habits of this animal in a state of nature are comparatively little known. The puma, one of the two great cats of America, figures in many a stirring story, where it is generally represented as instinctively friendly to man. But it is terribly savage to horses and cattle.

cousin. Except that the tiger is lower on the leg and slightly longer in the body, the differences as to structure are less notable than the resemblances. In habits the two beasts are closely akin, although the lion apparently likes the company of his own species more than does his striped kinsman, who prefers his own society, associating with the female only at certain parts of the year.

How is it, then, that the tiger abounds in every jungle and in every extensive patch of reeds and grass, while the lion has been exterminated? One answer has already been given. Another is that the tiger is less restricted in choice of shelter than the lion. The latter has no "den," but the tiger has. While he will make his home in the jungle or in high grass and swamps he is equally at home in caves or clefts of rock, and among the ruined buildings of deserted cities. He is perfectly comfortable, too, in pestilential districts into which white men dare not penetrate. His sanctuaries, therefore, are manifold. But the curious thing is that, where one tiger has been, another is certain to follow after the first has been destroyed. The tiger occupies his predecessors' haunts as surely as mice and rats take up their residence in runs where other mice and rats have been.

AN HEIR-APPARENT OF THE ANIMAL KINGDOM

The lion cub, not yet having attained to the dignified mien of the king of beasts, looks, and is, a frolicsome beast, easily tamed, and quite safe until accident reveals to it its physical superiority over man. Its play, when wild, is simply a natural training for the serious encounters that await it in maturity.

A good swimmer, the tiger covers a wide range in his immediate neighbourhood, swimming out to an island by night, and returning to shelter before dawn. He is essentially a nocturnal animal, and dislikes heat even more than the rest of his family. The late Sir Montagu Gerard saw for himself one reason why the tiger should avoid the daylight. A beast which Sir Montagu was pursuing under a broiling sun was observed to be very lame, and to leave bloodmarks on the stones. When shot, it was found that its pads had been actually burnt off by the scorching rocks over which it had fled.

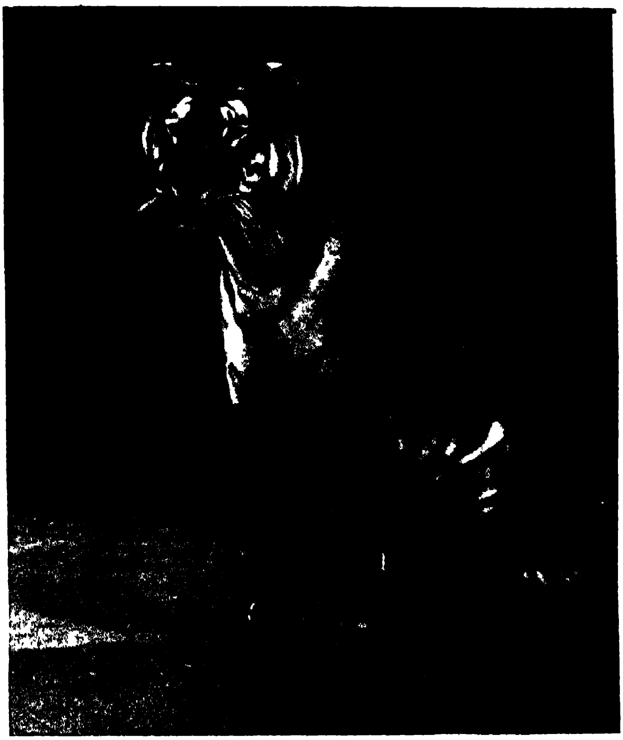
The natives of India make little attempt to combat the ravages of the tiger. They commonly surrender their cattle, knowing that, if they fail to do so, ill may befall themselves. But we have recently seen from what a remote cause tigers may take to man-killing. Upon a certain day in 1909 there occurred a cyclone and tidal wave in the Sundarbans portion of the Khulna district, in Bengal, and many deer were drowned. Consequently, there was a smaller supply of food for the tigers which swarm in this district. They took to killing human beings in default, and the return of deaths in 1910 was unprecedentedly high for the district.

In the cat family the leopards come next in importance to the tiger. Though smaller than either the lion or tiger, they are certainly little less to be feared. The tiger makes a prodigious upright leap in pursuit of a man who has sought safety in a tree, but the animal cannot climb; neither can the lion. The leopard, however, like its cousin the jaguar, is a magnificent climber. It is common to Asia and Africa, and is generally distributed throughout most parts of India. Over fifteen thousand leopards have been destroyed in India alone within the last three years, but they have caused the loss of over a thousand human lives in the same period. These figures do not, however, represent anything like the number of encounters with men in which the leopard is involved. It is really a greater menace than the tiger, inasmuch as it more frequently attacks human beings, not necessarily with fatal results. The leopard haunts

villages persistently, killing and carrying off ponies, donkeys, cattle, sheep, goats, dogs, men, women, and children. Dogs, curiously enough, are his favourites; and there are parts of India in which not a single dog is to be found, so thorough have been the operations of the leopards.

While he will attack a man with less provocation than will a lion or a tiger, the leopard also shows much greater boldness in broad daylight, nocturnal animal though he is. As a proof of this may be mentioned the experience of the late Sir Edward Bradford when out in Rajputana. He had invited forty Europeans to a picnic, and these, in addition to a numerous staff of servants, were assembled at the base of a small cliff. Sir Edward had two white terriers with him; and one of the guests, happening to look up, saw a leopard peeping down at the dogs from a point a hundred and fifty feet above. Sir Edward was warned that the big cat had designs upon his dogs, but he could not believe that the animal would venture from such a height into the midst of a crowd of men and women. Yet within ten minutes the leopard did venture, creeping down, making a dash among the startled company, and getting away safely with one of the terriers in its mouth.

Leopards vary considerably in size and weight, from specimens which may measure eight feet, down to the smallest, measuring only five feet from muzzle to tip of tail. The habits of all are very similar; they differ chiefly in the size of game they attack. Many people in African settlements fear this animal as much as the lion. Its ubiquity, its silent stealth, its daring, and its all-consuming appetite make it a much-dreaded foe.



THE TIGER, INDIA'S KING OF BEASTS

The tiger is pre-eminently the animal of India, where the lion is now nearly extinct But it is in Siberia that he attains his greatest size, strength, and luxuriance of coat. The tiger levies heavy toll on human life in India, and many a village has been depopulated through the agency of this animal.

Between the true leopards and the jaguar comes the snow leopard, a smaller and slimmer animal than its American cousin, mainly inhabiting the high-lying lands of Central Asia. Here, in summer, it is said to ascend to a height of over 18,000 feet, and never to come lower than half that level, except in the Gilgit district of the north-west Himalayas, where it is reported to be found in winter as low down as 6,000 feet. Although captive species have not been uncommon, our knowledge of the snow leopard in a state of nature is limited.

We know more of the jaguar, the king of the New World cats. The natural history of this splendid beast of prey has been carefully worked out. Exceptionally large specimens may reach a length of eight feet, or even more, but the average is considerably smaller. The jaguar is built on sturdier lines than the leopard, with enormously powerful limbs and paws. His home is in the semi-tropical forests of America, but he ranges far afield, as stockkeepers are only too well aware.

A superb swimmer and climber, he is called a "water cat of arboreal habits." His prey are the tapir, peccary, deer, ant-eater, agouti, birds, monkeys, fishes, and even young alligators. In addition, he levies toll from herd and flock, and is greatly dreaded as a man-slayer, the more deadly because he can lie perfectly concealed in a tree, to drop down upon the head of a man passing below. He will do battle with any animal he meets. He can kill an ox and drag it into cover; he can kill a horse. Zoologists sometimes think the disappearance of the prehistoric horse from the American continent may have been due to the great number of jaguars and pumas.

The jaguar resembles the leopard in its spots, and is called the American tiger. The puma, which is unspotted, is called the American lion. This animal is a terrible scourge where horses, sheep, and cattle are bred, and was at one time so formidable an enemy to the semi-wild horses of Patagonia that the herds dwindled away, finding it impossible to protect their colts from this lithe and powerful beast. The puma is inferior only to the jaguar in size, and is just as magnificent a climber; and the fact that it makes many a meal of the active American monkeys is sufficient evidence of its prowess. It is simply omnivorous in its tastes, and will eat anything, from a pig to a porcupine, from a horse to a snail. The most interesting thing about the puma is the fact that it will not, unprovoked, attack man. The point was long disputed, but the evidence of many men has induced our most serious naturalists at last to believe that there is some justification for the old name given to the puma by the Spanish settlers, "Friend of the Christian," and that where pumas abound it is safe even for little children to wander. Whether the puma will beat off a jaguar which seeks to attack a human being has still to be proved, though there are many stories to this effect. It is safe to believe, at any rate, that man is not liable to attack from jaguars where pumas are, if only for the reason that the innate hostility between the rival families may induce the puma to chase the jaguar from what he chooses to consider his own special area.

The last of the great cats is the clouded leopard, an animal restricted to life in the trees, where it lives on birds and small animals. Seeing that this beast may measure as much as six feet, there is reason to be thankful that it confines its operations to life above the ground. As a terrestrial animal it would add another terror to the natives of south-eastern Asia, where it finds its home.

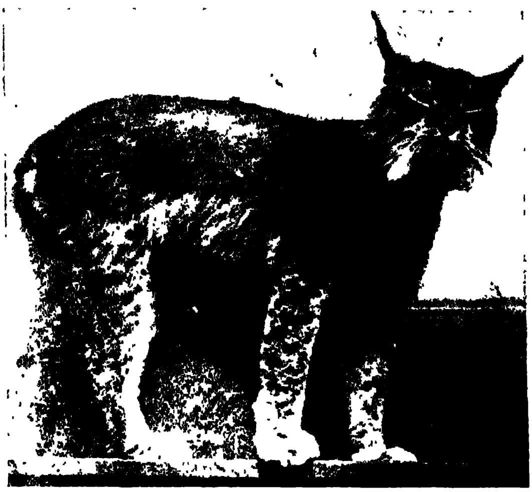
There are many other members of the cat tribe among the wild hunters of the world. There is the golden cat of the Indo-Malay area, which has a grey Chinese representative; there is the fishing cat, which not only eats the molluscs of Indian and Chinese swamps, but will eat sheep, dogs, calves, and even young children left unguarded. It is but little larger than the domesticated cat, but seems to have the ferocity of the genus in concentrated form. The leopard-cat, the servals, the tiger-cats, the eyra – which is the weasel of the cat tribe – the Egyptian or Kaffir cat, from which it is believed the domesticated cats of Europe originated – these and others bring up the rear of the hunting cats, in which are also included, of course, the wild cats proper, some of which still survive in the more remote deer-forests of Scotland. The family tree closes with the lynxes, a widely distributed group, found in Europe, Africa, Asia, and America. Its habits vary with the locality. In Europe it is an expert tree-climber; in Tibet it is quite at home in barren country among rocks and open ground. But wherever the animal may be found its nature is the same; it is sullen, ferocious, rapacious, with a delight in slaughter far beyond its needs.


THE CHEETAH, WHICH IS USED BY INDIAN PRINCES FOR HUNTING

PHŒBUS APOLLO HARNESSES THE LIONS TO THE CHARIOT OF THE SUN

Apollo, called Phœbus, or the sun god, in Greek mythology, is recorded as having driven the chariot of the sun. The power of knowing the future gave Apollo a high place in the Greek Pantheon, and he was the only one of the gods whose oracles were held in general repute over the ancient world. This fine picture, called "Phœbus Apollo," is by Mr. Briton Riviere, R.A., and now hangs in the Birmingham Art Gallery.

The cheetah, or hunting leopard, is included among the leopards by some zoologists. But it is not a leopard. The highest opinion refers the animal neither to the cat tribe nor the dog tribe, but to a genus of its own. The important difference first noticed is that the cheetah cannot draw its claws back into their sheaths, as all true cats can; they remain partly protruded, more after the fashion of the claws of a dog. There are important features in regard to the teeth, and the singular slimness of the body and its immense length of limb give the animal an unmistakable outline. It is common to Africa and India, but in India it is famous as a courser. It is caught when young, and trained to pursue and kill game; and Indian princes keep cheetahs for this purpose as Englishmen keep dogs and hounds.



THE SAVAGE LYNX

...lely distributed ove[r] the Old World and the New. We ... ver ... [wher]e found they ar[e] savage rapacious animals, killing birds ...es, sheep, and oth[er] animals larger than themselves in gre[ater] number than they [c]an possibly need for food.

The training is long and difficult. No cheetah bred in captivity, it is said, can ever be made into a successful courser, and the captive is not considered perfect until full grown. When he is to hunt, the cheetah is carried, hooded, upon an open cart to a spot where game is to be found. As soon as a buck is sighted, the hood is withdrawn from the cheetah's head. In a moment he sights the game, drops down from the cart, and begins to stalk low and creeping, as a cat stalks. When the quarry gets on the move, however, the cheetah flings caution to the winds, and launches himself like an arrow in pursuit. As a rule, it is all over in 500 yards. The buck is caught and thrown and pinned by the throat. It is said that for two or three hundred yards the cheetah can travel at the rate of a mile a minute. Should he not catch his quarry within 500 yards, however, he gives up the chase, lies down, and waits for the cart to come along and carry him. If the buck has been brought down, the huntsmen rapidly approach, draw a ladleful of blood from the victim, and offer it to the cheetah, which is still holding on to the deer's throat. The beast at once relinquishes his grip to drink the blood, and while he is thus engaged the hood is slipped over his head, and he has to wait until evening for his meal of flesh from the animal he has killed.

The wild cheetah is very tenacious of life, and one has been known to charge at astounding speed for 140 yards with a heavy bullet clean through his heart. This, however, is characteristic of all the great cats. Lion, tiger, and leopard will charge again and again with limbs smashed, riddled with bullets. Carl Hagenbeck had two snow leopards in 1906, both of which lacked a hind foot, torn off in some villainous trap. But in spite of their sufferings the animals survived and bred. The great carnivores, in the natural state, stand misusage almost as well as reptiles, and are as hard to kill, which brings us back to the thought with which we opened this chapter—the wonder that man should ever have survived his early combats with such terrible rivals on the earth.

THE JAGUAR, WHICH CLIMBS AND SWIMS

The jaguar, which is practically as formidable in strength and ferocity as the lion or the tiger, has an advantage over both in that it is a superb tree-climber, as well as a notable swimmer.

THE VEDDAHS OF CEYLON, PROBABLY THE MOST PRIMITIVE PEOPLE NOW LIVING IN THE WORLD

The Veddahs of Ceylon, generally regarded as the most primitive tribe in the world, represent the lowest stage in human development. It is believed that they descend from the original inhabitants of Ceylon, where they now live in a territory by themselves, preserving habits and customs unchanged for 2000 years.

From a photograph by Skeen & Co., Colombo

THE PRIMITIVE PEOPLES

Qualities of the Lower Races of Mankind, and the Invasion of Their Territories by Civilisation

TYPES OF MEN DOOMED TO DISAPPEAR

We have gone so far as to assume, with all modern authorities, that the human race had a single origin, and have found reason to place the site of that origin in Asia. The first creature that could possibly be called man arose there, and began to spread in all directions, impelled by hunger, curiosity, love of adventure—those same motives which urge the pioneer and the traveller to-day. But wherever he went he remained a single species, the human species, and to this, in a generous spirit, systematists have given the name of *homo sapiens*—man the wise.

We shall grant, then, that all the human beings now upon the earth own a single ancestry, and that they all belong to a single species, *homo sapiens*, so that, however various its members may be, they are all human, and can all produce offspring with one another—as readily, it would appear, with extreme intermixture of race as with none. This, we may remember, is one of the classical tests of what is usually understood by a "species," and on this test all *existing* men belong to one species.

We have, of course, some title to speculate as to definite human forms in the past, and may give them names which assume that sapience or wisdom is only a modern product. Thus, we may speak of *Homo neanderthalensis*, represented by the famous Neanderthal skull, or of *Homo primigenius*, primitive man, or of a supposed *Homo alalus*, or man before speech. But whatever these names and speculations may lead to, they do not help us much as regards existing man, who is now our problem.

He is found all over the world, alike in the tropic zone which bore his first parents, in temperate and in polar regions. He presents enormous variety of physical form, and of social form and culture. The mighty fact called society, and the social heritage, rich or poor, which is transmitted from generation to generation, outside the realm of the "germ-plasm," complicates incalculably the problem of the anthropologist. If there were no such thing; and he had simply to deal with creatures like animals, which are in practically no degree social products, then he could confidently assign their natural rank to the various kinds of men whom he surveys. But that is not the problem before him. He has to reckon with culture and education, and tradition, and institutions; he cannot instantly determine, on mere inspection, whether an apparent barbarian may not be simply a "rough diamond," and he may be constantly mistaken in individuals, well dressed, fair spoken, and elegantly groomed, who turn out to be little more than veneered savages.

Needless to say, there is a slap-dash method of judgment, mainly depending on skin-colour, which wastes no time with these refinements. If we know what we—or, rather, the race-prejudice of which we are the slaves—want to believe, our difficulties are at an end. Anyone who is not just like us is a "native" or a "foreigner"; anyone whose skin is more highly pigmented than our own is a "nigger"; any language we do not understand is a jargon. To the shaven Greeks all other peoples were the bearded, or, in Greek, the "barbaroi." To most of us to-day anyone who is not just of our pattern is still a barbarian, and all men whose civilisation is not modern civilisation are savages. But the time for all that is past. Science, which ceases to be science the instant it entertains a prejudice, has to study these facts impartially as it studies the varieties of atoms; and its verdicts are

frequently in direct opposition to what prejudice or even mere casual inquiry suggests.

So far, indeed, has the pendulum swung since the old days that a new prejudice has to be faced and discountenanced by science. Only this year—in 1911—there was held in London a Universal Races Congress, in which this new prejudice had a liberal hearing, if, indeed, it did not drown the voice of science. It is to be spoken of with the utmost respect, for it is humane and generous, but it is vain. Whereas, on the one hand, men err profoundly when they seek to dismiss as inferior all forms of civilisation or society which are different from or simpler than their own, yet, on the other hand, the view cannot be maintained that, if only we would allow for differences of culture and opportunity, all races are equal. It is not so. Race is a fact, and the differences between races are facts. These differences are more than skin deep. They extend into the realm of nerve and mind, and involve superiority here and inferiority there.

The Differences of Race which Go Far to Explain Race Prejudice

If this be a fact of science it must be accepted, as all such facts must. It goes far to explain race-prejudice, but it offers no justification for race-prejudice. It goes far to explain the conflict between races and the horrible incidents of such conflict, but it offers no justification for the savage treatment of savages by civilised people. We must sharply distinguish, once and for all, between the scientific statement of facts and any judgment upon the moral questions which those facts are bound to raise. Science, perfectly indifferent to the colour of the skin, examines the brain of the white man and of the black. It finds both brains white, as all brains are, and its impartial judgment is in favour of the white man's brain. Religion and ethics have to deal with the problems involved. They must neither bully science to deny what it knows, nor must they confound the verdict of science as to what is with the question of what ought to be.

Here we have referred to the races in question as primitive, a term which definitely suggests that they represent an earlier stage of human development than the races who do not come into this category. The term will probably remain in general use, and it is certainly a better term than "savages," but there are serious objections to it, as science is now beginning to discover.

In the first place, it is quite certain that no existing races are primitive in the sense that they represent primitive man. Of that we may be perfectly confident. Primitive man, and many stages of development later than his, have gone for ever. We need not turn to the lowest of existing races in the hope that we shall find primitive man before our eyes.

The Mistaken Impressions of the Missionaries about the Lower Races

In the second place, there is a fact called degeneration, which is probably as common as any of the major facts of human history. In older days missionaries always assumed degeneration in religious belief. Missionaries were largely the pioneer anthropologists, and we need not despise their efforts. When they found rude peoples who believed in many deities, and whose religion was to be called polytheism, missionaries assumed that this was a degeneration from an aboriginal monotheism. That view cannot now be held, for the evidence is clear that polytheism represents an earlier stage of religious belief. But nowadays we are not at all so certain that the missionaries were entirely wrong. In various parts of the world, often in circumstances of more or less physical isolation from the rest of mankind, as in Papua or Ceylon or Tierra del Fuego, we find human beings who seem ruder and lower than any others, and we promptly label them primitive. Commonly they are living in conditions of extreme difficulty, near to starvation, much exposed to an inclement climate, and unable to do any better for themselves.

The Real Character of Men Living Apart from Civilisation

In such circumstances reason and analogy would suggest that we are dealing, not with a primitive people, but a degenerate people, and that we must therefore be wary of drawing conclusions from their condition, which may tell us no more of the real truth than would an examination with similar assumptions of the slum population of one of our great cities.

In the world of life, descent is at least as easy as ascent; nay, it is far easier. When human beings live in dark forests, on barren island shores, on sterile soils, near the Poles, or otherwise under physical conditions of extreme rigour, they are no less liable to degenerate than are beings of any other living species in parallel circumstances. Races of these kinds can be studied with interest and profit, so long

LIFE PICTURES OF PRIMITIVE PEOPLES

A GROUP OF KAFFIR WOMEN SITTING WITH THEIR CHILDREN

THE AINOS OF JAPAN

The most primitive native race of whom any trace can be found in the island empire of the East

PEOPLE WHO LIVE IN TREES

The natives of New Guinea, shown in this photograph, still build their houses in trees

KAFFIR CHILDREN AT THE DOOR OF THEIR MUD HOUSE

The pictures on these pages show types of primitive peoples, but it should always be remembered that no existing races are primitive in the sense that they represent primitive man. Nor are the "primitive" races necessarily degenerate. We mean by primitive races people displaying primitive forms of civilisation and culture, and of such peoples this page gives us three types, the pictures of Kaffirs being taken by Mr. Dudley Kidd, whose "Savage Childhood" is a delightful book.

as any of them remain, but we should not call them primitive. They have gone back to Nature, but they have gone too far.

The truth is that Rousseau and his followers, entirely destitute of any anthropological knowledge, have too long misled modern men as to the character of those who live apart from any form of civilisation, with what that demands and what it supplies. The "noble savage" who throve in a state of Nature before man invented civilisation and spoilt everything—this delightful being never existed. The argument of Rousseau and his school that "all civilisation is a state of social degradation," and that "the primeval savage life is the state of human simplicity and perfection," is as gross and ludicrous a perversion of the truth as ever a clever man deceived himself with. When we study existing men who live under the conditions which Rousseau desired, having no property, no laws, no government, none of the social inequality which he, very rightly, no doubt, denounced, the last thing we find therewith is human happiness and dignity. If natural man has favourable enough conditions, he multiplies, and his multiplication makes civilisation of some sort necessary.

The Sad Life of the Man of a Savage Race

If he tries to face Nature in his natural state, his nakedness and weakness of body being thus unaided by his mind, his life is not worth living. As a modern writer has forcibly put it, mankind can no more go back to Nature now than any one of us can return to his mother's womb.

These savages, as we may justly call them, provided we do not refer to their temper—for they are not savage in disposition—are literally degraded, and drag on an existence which is scarcely to be called human. They are commonly undersized and emaciated. Their minds seem full of superstitious fears and horrors. Their incessant problem is how to live and find shelter. They are the prey of innumerable parasites, and become senile in their thirties; and they represent the quality of mankind in its naked state of mind and of body, for they have no social heritage, and thus nothing but the merely physical to transmit to their offspring. Before we condemn and despise them, we have to decide exactly what we ourselves would have amounted to had we been born and reared under such conditions of physical rigour, and without the vestige of a culture to assimilate. "Self-made" men, in a stricter than the usual sense, what reason should we have had to take pride in our achievement?

But above and apart from these races of more or less degraded savages, we find other peoples, in almost all parts of the world, such as the Maoris and the Zulus, who are still very remote from ourselves, but who cannot possibly be ranked anywhere near such indigenous races as the Veddahs of Ceylon, or the Ainos of Japan.

The Races of Men Who must be Studied Quickly before they Disappear

If the word "primitive" is to be used at all, it should be applied to such races as those to whom we are now referring. They show no signs of degeneracy—until we begin to civilise them, that is to say—and though they are æons apart from "primitive man," they do display primitive forms of civilisation, and of culture. Our contact with them modifies their culture, and involves their slow, or even rapid, extermination. They must therefore be studied quickly, or not at all; and this study must include both physical anthropology—which is, indeed, of lesser interest—and the study of their minds and beliefs and customs.

The physical anthropology of such races need not long detain us. The general conclusions to be drawn from it are definite enough. The main facts of anatomy and physiology, thus compared in different races of men, entirely justify the belief that all human beings now extant, whatever may be the case as regards extinct forms of man, belong to one species. Nevertheless, differences in skull-form and so forth are certainly to be found; and in these respects the advantage lies with what we call the great races, though their inherent and natural advantage is much less than we are too commonly inclined to suppose.

The Effect of Climate and Environment on the Characteristics of Races

The recent work of Professor Franz Boas in the United States must also be noted in this connection, for his study of the children of immigrants of various races suggests that climate and natural environment modify racial characteristics as few had hitherto supposed, even to the extent of radically altering the proportions of the skull, which anthropologists have for so long been disposed to regard as immutable throughout the ages.

As regards skin-colour, so superficial, and therefore so conspicuous and notable, and therefore also so insignificant, the

modern evidence suggests that this race-character is profoundly modifiable by environment or, to be more precise, by the quality and quantity of sunlight. Major Woodruff, in the United States, has gone far to show that skin pigmentation is protective, guarding the blood and deeper tissues from the powerful action of the "chemical rays" in the sunlight. This pigmentation becomes very marked even in the skin of the white man when he is exposed to the tropical sun, and it must be remembered that the white man is only relatively white, having pigment and pigment cells in his skin, and being quite distinct from the really white man, who is abnormal, and termed an albino.

The Study of the Mind of the Primitive Races

Professor Karl Pearson has lately advanced the theory that the white races are an albino "sport" derived from the black, but this view has not found favour with any first-hand students of man.

When we turn from the physique to the *psyche* of the so-called primitive races, we find a field of the deepest interest and instructiveness, which would well accommodate a thousand times the present number of workers. Here the missionaries have taught us much, and modern missionaries teach us much more. The cause of pure science and human progress would greatly benefit if all who went as missionaries to the "heathen" could first receive at least a year's training in anthropology and in the methods and pitfalls in the observation of such peoples.

An important fact should be noted in dealing with the individual psychology of primitive peoples, which has led to much erroneous belief. It is more important than anything we can learn about their bodies, and it must be understood if we are rightly to interpret their societies.

The Degeneration of the Kaffir Boy as He Grows Up to Manhood

Observers have constantly reported that the children of lowly races, such as the aboriginal Australian, the now-extinct Tasmanian, or the rapidly multiplying Kaffir, compare favourably on all counts with European children. The view that such races are mentally inferior has been challenged on the evidence supplied by, say, competitive examinations for ten-year-olds of white and native races. The native children are just as intelligent as the white, just as charming and curious, and interested and lively, and lovable.

The same cannot be said, however, of the adult Kaffir as of the Kaffir child. Indeed, as Mr. Dudley Kidd and other first-hand students have taught us, the children of these lower races *degenerate* at puberty. The boys especially, when they become men, degenerate mentally; and their whole being and interests seem to be thereafter almost wholly confined to the channel of sex. This degeneration is much less marked in the women. In consequence of it, the native child may be the equal or the superior of the white child, but the native adult is inferior.

These observations raise matters which concern us all throughout our lives, as individuals, as parents, and as citizens. Here, however, they are to be looked at simply from the standpoint of the comparative study of man. They entirely consort with the observations which show that adult man everywhere is a degenerate form of the boy, physically speaking, as the growth of his beard, the changes in his voice, the development of his skull, and other characteristics testify. In all races this degeneration in bodily structure is liable to be accompanied by psychical degeneration.

The Boys of the Lower Races who are Brighter and Better than the Men

It is not only among Kaffirs or among the native Australians, unfortunately, that the boy is nicer, brighter, more original, more sympathetic, more interested, less selfish, more generous, quicker in memory and invention than the man; and it is the emergence of sex in both cases that makes the turning-point. In the lower races, sex would appear to be scarcely transmutable by self-control into higher forms of activity; hence the difference. The constant disappointment of missionaries and educators is thus explained.

If now we turn to estimate these lower peoples from the standpoint of their culture, we find occasion to revise almost wholly the older estimates. The student of our culture—apart from buildings and motor-cars and so forth—would require to live with us and gain our friendship, or, at least, lack of suspicion and hostility, before his observations could hope to go very far. Similarly, what we see in casual observation of primitive peoples on whom we have forced ourselves is a mere nothing, or, indeed, often wholly misleading. Prolonged inquiry under conditions which make any inquiry profitable reveals the fact that these supposed savages have a civilisation or culture of their own, which

is worthy of unending study, and often worthy of our profound respect.

For instance, on the mere score of complexity and complete working out of detail, the marriage system of the primitive Australians surpasses anything we can compare with it. It has taken decades of continuous study for us to gain any knowledge of it, much more of its meaning and origin. But there it is, with its recognition of relationships between individuals, and of duties of *taboos*, privileges, and restrictions, so subtle and detailed and rigorous that our social system is a chaos by comparison. No doubt ours is better, but the present point is that we cannot apply the name of savages to people who have developed such social institutions as Australian marriage.

A KAFFIR BOY

In certain fundamentals we still have everything to learn from primitive peoples. Though they are by no means living next to Nature, as are the rude races whom we have already discussed, yet they are in many ways nearer to the perception of essentials than we can readily be. Thus in such matters as the protection of girlhood and boyhood, of womanhood and motherhood, many primitive peoples have for ages practised what our most advanced reformers are still hoping to see the dawn of among ourselves. The Maoris or the Bantu know nothing of the neglect of youth which is part of our social practice. The Zulu mother is protected; the unmarried expectant mother is given to the charge of a young warrior, and the guilty father is assegaied. No woman, young or old, is unprotected.

A very natural and human question presents itself to the inquirer, and with it we must conclude our survey of these people. What is their future?

The answer must be, "It all depends." If they are brought into competition with Maxim guns and repeating rifles, merely "savage" weapons such as spears are wholly out-savaged. If the competition be of a subtler form, the primitive peoples still go under. Our diseases, and our ardent spirits, are too much for them. Very often they are killed by kindness even the missionary who persuades them to wear European clothes may hasten their end. The Bible does not go to them alone, and they have no chance against our brandy and our bacteria. In the case of the Tasmanians, it looked as if removal from their native island, and nothing else, prevented the race from continuing, just as the white man finds in the tropics.

But there are no inherent reasons why these races should disappear. Certain primitive Africans, under favourable conditions, have multiplied to many millions in the New World, where not a single negro existed until the white man imported them. There are some twelve millions of human beings whom man has simply *made* there. Though the death-rate is high from narcotics

and tuberculosis, the birth-rate is also very high. In general, we see that the survival of these lower races in the future entirely depends on the conditions to which they are exposed. Now that they are not simply to be shot down, they may multiply as never before, and where never before; or they may disappear. The African native is very far from disappearing, either in South Africa or in America.

The very lowest existing types of man are doomed. Many scanty tribes, here and there, each with its lesson, cannot long survive their discovery by civilised peoples. But the African native, especially furnishing a very fair sample of a primitive people, is certain to constitute one of the great world-problems for many generations to come. The verdict of anatomy and psychology in this case is perfectly clear. The negro does belong to an inferior race. His brain capacity is poorer, its construction simpler. His psychological type, *on the average*, is lower, most notably in the matters of judgment and inhibition, or self-control. It is in this respect that alcohol, and other drugs which paralyse self-control, are his great enemies.

If the anthropologist could report otherwise, no doubt he would. His study of mankind, and his interest in human types, tend toward humanity and sympathy with those whom he studies; and he has no desire to report anything which would lead to other feelings. But the interests of scientific truth are paramount, not merely because truth is truth, but because we must know in order to control, and because false hopes are not worth fostering. Our relation to the negro must be that of a big brother. Impartial students in the United States report very unfavourably on the influence of the race of lower psychological type upon the less controlled members of what is really the higher race. Many of the least pleasing features of American civilisation seem to be due to this vitiating factor. The psychologist will readily credit this argument.

On purely biological grounds, the intermarriage of higher and lower races is more than dubious; it is to be condemned, at any rate, as a general social practice. The intermarriage of races has never yet been clearly analysed according to the totally distinct groups, in one of which the intermarrying races are equal, and in the other of which one is inferior. The most sympathetic anthropologist, who knows the best as well as the worst of the primitive peoples, who would greatly regret their disappearance, and who desires to see the utmost possible made of them, is left no choice by the canons and conclusions of his science but to deplore the union of higher and lower racial types.

A KAFFIR GIRL

That, however, will increasingly be the problem which the future has to face, and which depends upon the survival of lower types of man and their contact with the makers of the modern world.

CHILDREN AT SCHOOL IN THE OPEN AIR

More and more it is being recognised that half the battle of education is physical, and the happiest *results have followed the experiments of open-air schools.* In Sheffield the experiment has been tried with the greatest success. The difference between life indoors and out of doors is fundamental, and the best ventilated room can never be quite so healthy as the open air itself.

A CEASELESS FLOW OF AIR

The Natural Enemy of Ill-health which is Within Reach of Every Home in the World

THE OPEN DOOR AND THE OPEN WINDOW

Though so much nonsense has been talked about "change of air," which usually means change of everything but air, there is no doubt that unless we have incessant change of air we die, and that is why we breathe.

We breathe in for one purpose, and out for another, the two being totally distinct.* We breathe in so as to help ourselves to oxygen, and for no other purpose. If that were the whole of breathing, there would be little difficulty, for there is plenty of oxygen in the air, and we need not fear to exhaust it. The real problems for health begin with the breathing out. It is what cometh out of a man that defileth. We expire or breathe out in order to get rid of poisonous products of our own lives; and if we fail to do this successfully, we expire in another sense.

Experiment shows that we can do without oxygen for a considerable period, provided that we be allowed to get rid of our respiratory poisons. The symptoms of suffocation or asphyxia are symptoms *not* of starvation, but of intoxication. Thus, when we inhale "laughing-gas," which prevents the blood from carrying its oxygen, we do not die, nor are we in danger at all of death, for the "laughing-gas" does not interfere at all with our getting rid of our poisons. If it did that, we should die at once, but it only deprives us of oxygen for a little, and so we merely lose consciousness.

This argument is of vital importance as regards ventilation and breathing, and as regards food and exercise and cleanliness. In these and all other cases it may certainly be laid down that the usual risk is that of poisoning. The body can stand much deprivation of all kinds, some deprivation of air, and great deprivation of food, exercise, and light, but it quickly succumbs to poisoning. Life has its reserves for emergencies, but if it be not allowed to rid itself of its waste products it is quickly choked, and dies.

When a room becomes stuffy, we suggest opening the window and letting in a little fresh air. Lack of fresh air is the cause of our discomfort and headache and drowsiness, we suppose. The fact is quite otherwise. We should speak of opening the window to let out a little foul air. So far as the oxygen need is concerned, we are no whit worse off in what we call stuffy air than in fresh air. There is a little less proportion of oxygen in it, but in any case there is more than we need, and our blood remains as fully saturated with oxygen in an unventilated room as in the open air. It is the products of our breathing that are present in the stuffy air, and cause our symptoms. They are not symptoms of starvation, but of poisoning. We prefer to speak of letting in the fresh air, for that sounds more elegant than letting out the foul air, but the question in these pages is not elegance, but truth; and truth says that we have been breathing over and over again the befouled air which our own lives have necessarily produced, and that we must get rid of it.

People who really understand this get to feel that sitting in an unventilated room and much more sleeping in an unventilated bedroom, is *dirty*, just as not removing the sweat from one's skin or not attending to other bodily demands is dirty, or just as the Japanese consider that to wash one's body in a bath, and then lie in the bath, is dirty. They prefer fresh water after washing themselves; indeed, they, and Eastern peoples in general, prefer running water in which to wash the outside of their bodies. Just so do wise people prefer running air in which to wash the insides of their bodies.

The difference between washing the inside of the body by expiration and washing the outside of the body by perspiration and the use of water is simply a matter of bodily

convenience. The two processes are essentially the same, and some animals, and nearly all plants, use the whole surface of their bodies to breathe out by, though we use only our lung-surfaces, which are deep inside the body. From the point of view of health, expiration and perspiration are both simply forms of excretion, just as inspiration and eating and drinking are different forms of absorption.

This argument helps us in the study of ventilation, because it prepares us to realise that the air in which we live is constantly being soiled, not only by what our lungs contribute to it, but also by what our skin contributes to it. Lungs and skin alike are getting rid of what the body does not want, and both are thus spoiling and soiling the air. Our clothes must necessarily be affected in the process, and soiled clothes substantially help to befoul the air. When one says soiled clothes, one is not thinking of mud or ink or paint or any such thing that has reached them from without, but the really objectionable dirt that has reached them from our perspiration. Numerous experiments seem to suggest that ventilation would be far less urgent a matter if people all kept their skins and their clothes scrupulously clean.

How our Personal Habits Affect the Question of Housing and Sanitation

The greater part of the offensiveness and the injury to health which distinguish crowds of people, indoors and out of doors, in this part of the world would disappear if they were as clean, as regards skin and clothes, as the Japanese are. A Japanese crowd is quite odourless, for this reason, but the expired air of a Japanese crowd is exactly the same as that of a crowd in an English slum. The gases found in the air of an unventilated room will experimentally cause symptoms of faintness, headache, sickness, fatigue, and so forth. But if the experiments be made with the gases found in expired air—thus not including those produced by skin and clothes—these symptoms are much diminished, and indeed can often not be produced at all, so long as sufficient oxygen be supplied.

These recent results of science are of much more than merely theoretical importance. They prove, to a degree never formerly suspected, that the problem of ventilation, of hygienic architecture and housing, is largely complicated with, and modified by, the problem of personal cleanliness. In short, ventilation is not merely a problem of air supply; it is scarcely less a problem of soap and water; and the air of a house is kept pure not only by the open window, but also by the bath, the tub, and the laundry.

However, we are not yet by any means ready to tackle this gigantic fundamental problem of ventilation, which sounds so simple, and is so often insoluble; but when we do come to it, whether on the printed page or in the railway carriage or church or bedroom, we must always realise, in future, that ordinary cleanliness is part of it, just as expiration is itself an act of cleanliness. We must realise that internal and external cleanliness are parts of one whole, and can never safely be divorced.

The Importance of Washing in Flowing Water and Breathing in Flowing Air

Meanwhile, we have some more first principles awaiting our attention—though none of more importance than those which teach us that to enter, say, a third-rate music-hall at "half-time" is for all practical purposes, and on all scientific grounds, just as clean and pleasant an act as entering a bath in which half a dozen people have already washed themselves. Of the two, the bath, provided one kept one's mouth shut, would certainly be much less dangerous, for none of the dirt would enter one's body.

The dirt in the air of the modern music-hall, air into which so many people have been washing the insides of their bodies and their skins and their clothes, can partly be filtered by one's nose, but much of it inevitably enters the body. This is not very pleasant reading; but half the duty of the teacher of health is to show people how disgusting—if they only knew—are many of the things they do, and then they do them no more. We must disgust people about the composition of street-dust, for instance, or they will continue to trail their skirts in it, and buy milk and meat that have been exposed to it. The writer apologises, therefore, but he will persist.

The Only Kind of Night Air which is to be Feared

And now for the next principle of health and breath, it being agreed that one should wash in flowing water and breathe in flowing air. We see that, in this part of the world at any rate, where there are no aerial insects outside to inoculate disease, we should open our bedroom window at night. Not to do so is to expose ourselves to the only kind of night air which is to be feared—that which we make ourselves in our own bedrooms. Our fathers and mothers used to shut

THE JOY OF THE OPEN AIR—FROM THE FINE PICTURE, "CUBBING WITH THE YORK AND AINSTIE," BY THE LATE CHARLES FURSE, A.R.A.

their windows in order to keep out the dangerous night air; we are to open our windows in order to let it out. It matters less that windows should be shut so long as rooms are not inhabited, though doubtless they are better open. It is when we live in a room that the window requires to be open. The common practice is to "air the room" when no one is doing the air any harm, but to close the window when we enter the room and proceed to spoil its air. No one would really follow this absurd custom if the principles of the subject were understood. We do not run the water through the bath when it is not being used, but we should run it through the bath *when it is being used*.

By opening our windows we obtain air, and avoid the process of partial suffocation to which we should otherwise be subjected. But we are now beginning to discover that, though fresh air is a very good thing, it is by no means the same as open air.

At first one is apt to think that fresh air and open air are the same thing, but the two terms should never be used synonymously. Open air is doubtless fresh air, but fresh air is not always open air. "Tube" air is, on the whole, remarkably fresh, and it sustains life without substantial immediate injury even to those who breathe it all day. The air of a modern coal-mine is also wonderfully fresh, or that of a modern hospital, but none of these is open air.

This may sound like a mere quibble, but it is a very serious matter. The present writer will never forget the lesson taught him by a patient who had been living in the open air on the balcony of a hospital pavilion for some weeks, and was brought into the ward for the purpose of a special examination of his chest. He complained bitterly of the air, and his temperature actually began to rise, but to everyone else, including young athletic students much accustomed to the open air, the air of the ward was perfectly fresh and pure. No chemist could have detected any difference in its composition. Indeed, it was the very same air which had, a moment before entering the ward, been passing across the balcony.

This was no isolated case. The experience of recent years has taught us that the open air has virtues of its own which enclosed air, however rapidly it be changed, can never hope to possess. When people who remain ill in fresh air are made to live in the open air they often get well. When children who have pined and been put down for

stupid in well-ventilated classrooms are sent to an open-air school they often become healthy and vigorous and attentive and intelligent. There is something in the open air—what the French call the "full" air and the "great" air—which cannot be imitated under any artificial conditions whatever.

The fact must be stated, because it is so important for health, and because it is bound ere long to influence our town-planning and our schools and our houses, and, indeed, half the habits of the community. But it would take too long for us to follow all the experiments and arguments by which it has been sought to explain wherein lies the difference between open air and mere fresh air. Here we can note only two or three points. Each of them is probably an important part of the whole truth, and has plenty of guidance for the wise.

Life in the open air is superior to living in any enclosed space, however well ventilated, because any enclosed space is constantly apt to become an infected space. It is part of the inevitable nature of all living things to vitiate their surroundings; if they are to keep themselves pure, they have no choice in the matter.

The Difference between Fresh Air in the House and the Open Air Outside

Directly we encamp, whether in the virgin forest or in a house, we do a risky thing. Floor, walls, roof, furniture, carpet, hangings, all become possible and probable sites for harbouring infectious organisms, which we ourselves, in our goings and comings, are certain to provide. At the very best, we can only hope to maintain, indoors, conditions practically as good as those out of doors by the incessant practice of cleanliness. To admit the open air is vastly important—indeed, it is essential; and if we do so freely enough we may boast we live in fresh air indeed. But the fact remains that the fresh air, however fast it flows, is flowing through and over all manner of surfaces which involve some measure of danger to health. Therefore, though the air be one and the same inside and outside, to live inside and to live outside are not practically the same thing.

In so far as this argument is sound, the moral of it simply reiterates the moral of our discussion of excretion by the lungs and by the skin. We must keep our homes, and our places of business and amusement—in short, everywhere that is not completely out of doors—cleaner than ever. Once more the problems of air and of ventilation are found to be all mixed up with the problems of cleanliness.

This point demands the most insistent and often-repeated statement. A park is presented to a city, and we use such phrases as "another lung for London." Parks are splendid things, but they do no good as "lungs," except to the people who at any given moment are in them. The dirty houses, with closed or with open windows, dark and dank, harbouring all manner of infection, from countless past cases of infectious disease—these, which look upon the park in question, are just as insanitary as ever they were.

The Tiny, Unventilated Bedroom which Killed Grace Darling after her Life by the Sea

There is a fallacy in the minds of the public and politicians and social reformers in this respect. Parks let us have by all means, and a garden, as large as you like, for everyone's house, but they will not save or prolong a single life if people do not *live in them.* Grace Darling spent half her life, or two-thirds of it, in the open sea air of the Northumbrian coast, which far surpasses that of any city park, but she spent the remaining third of her life in a tiny, unventilated bedroom, and she died of consumption. Just so are hundreds of thousands of people now dying in our cities, while our parks and open spaces can do no more for them than the glorious night air of the North Sea could do for Grace Darling when she was in her bedroom. Parks are splendid for the things that live in them—for their grass and trees all the time, and for people—how much of the time?

Now for the second reason why open air beats mere fresh air. It is simply that open air means, on the average, far more light than fresh air. We know too little yet of the influence of light on human health and development. It is to be remembered that *there is much more in light than meets the eye*—rays invisible, but none the less potent.

How the Sun, pouring in through the Window, Drives away the Microbes

So obscure is this subject, and so very much neglected hitherto, that it is doubtful whether our knowledge of it would fill a single article of this section, though it is very likely that the real importance of it for health would entitle it to half a dozen. At any rate, what evidence we have suggests that the visible and invisible forms of solar radiation powerfully affect the body in many ways, and that their effects make for health, by their action on the skin, their absorption by the blood, and their

stimulation of the eye, and their further stimulation, through the eye, of respiration.

But even if the direct influence of light upon the body were nil, its influence upon health would remain incalculable, because of its destructive effect upon microbes. The germs of disease cannot face the light; and one of the greatest differences between living in enclosed air, however fresh, and living in the open air, is that the open air and the surface of the ground under it are so free from microbes, because of the antiseptic action of light. If this be added to the direct action of light on our bodies, the two facts, taken together, constitute an enormous hygienic advantage for life in the open air.

The Stimulating Effect of a Walk in the Rushing Wind

A third reason why open air is best is simply that it is much more in motion. We are apt to fear draughts, but few of us fear the motion of the open air. The breeze, the rushing wind, these not only make for health by their direct production of "change of air," blowing away our expired breath, but also by their stimulating effect upon the body. There is reason to believe that much of our health depends upon processes which are started through stimulation of the skin. All these new-fangled treatments by friction and massage and vibration, and also the fashionable bathing and rough towelling, owe their virtues in chief degree to their stimulation of the skin. Now, that is what the open air almost always does, except upon the very stillest day. It is, indeed, the second best stimulant in the world—second only to sunlight itself.

Its stimulant action is very readily seen when we find ourselves inclined to move about in the open air, as we generally do. It persuades us to take a brisk walk, or to run, or play. We thus are inveigled into taking exercise, and exercise combines with the stimulant action of sunlight upon our breathing to make that vital process deeper and more complete.

The Precious Qualities of the Open Air which can never be Reproduced Indoors

The students of this subject are agreed, on all these grounds, that the open air is not only the best air, but that it is, and always will be, inevitably superior to anything else. Air may be filtered, moistened, scented, warmed or cooled, ozonised, electrified—what you will—and thereafter pumped, in the fullest quantities, into any kind of building. It will never rival the open air, and now we know why. It used to be said, before the days of exact and critical science, that the air lost some "vital principle" by such processes, and that because it was thus "devitalised" it proved inferior for life and health.

We now know that this is inaccurate. Air contains no "vital principle," in any sense of the words, except oxygen, and any air contains more than enough oxygen for the maintenance of life. The only occasion on which to speak accurately of air as devitalised would be when all the living microbes in it had been filtered away or killed. Such "devitalised air" would be the best for our vitality. But, as we have proved, it is profoundly true that no artificial processes can ever reproduce indoors, whether in a palace or a hovel, a scientific laboratory or an Eskimo hut, the qualities of the open air.

To the policy of the open window, which our age has lately adopted, there must therefore be added the policy of the open door. Man is the master of Nature, but only on her terms. There are limits which we cannot transcend; and though we pretend to ourselves and each other that we can, Nature is not mocked. The unique and irreproducible value of living in the open air is a case in point. No further advice need be given to the reader than to remind him, in the most pointed and personal manner, that a word to the wise is sufficient.

The Policy of the Open Door and the Big Window

It has to be admitted that we cannot possibly spend all our time out of doors, and that the hygienist must do his best in advising how most safely we may live indoors. His first duty is to insist on the policy of the open door, and protest that nothing else can take its place. Thereafter he must argue for the open window, of course, by night and by day, and for the making of windows as large as possible, in order that, whether they be open or shut, they may admit the light. Glass, by the way, absorbs certain rays of sunlight which are probably most valuable for health, so that the open air has the advantage again, unless glass be abolished altogether.

For the rest, we must do what we can in the way of ventilation. Ten years ago, the hygienist would have written with enthusiasm on this subject; the present writer did so himself. To-day one feels rather differently. The text-books are full of descriptions of the various modes of ventilation—natural ventilation, such as the open window, and artificial ventilation by the *vacuum* system, which sucks the

foul air out, and the *plenum* system, which pumps the fresh air in. These questions concern us all from the point of view of public health and the proper construction of cities and buildings. They do not come into the present discussion, however, for here we are concerned only with personal hygiene, with our own health and conduct.

Why we Should Always Open the Window when we have a Fire

Most of us have to live where we can, and to enter what buildings we must, and the problem for us is to do the best we can in the circumstances. We have some control over the arrangement of our own homes, and for that we are responsible to ourselves and to those who depend or will depend upon us.

The policy of the open window must be not merely preached or acquiesced in, but practised, by day and by night. Common sense suggests that we shall obtain more comfort if we open the window at the top. Some people like to open the lower sash, and insert an obstructive prop beneath it, so that the air can only enter in an upward direction, between the two sashes. This is not worth doing, for the air does not maintain its upward direction after entering the room. The atrocious sandbags of the last generation will find no place in our houses. On no account will we ever close our chimneys, for they are most valuable adjuncts to ventilation. When the fire is burning it is reckoned that air passes up the chimney at the rate of about three feet per second, and this must, of course, be replaced in the room by the entry of fresh air from without. But even when the fire is not burning, as in summer, the chimney is a valuable outlet shaft, and should never be obstructed by the useless lid builders still provide, nor by any kind of decoration. Any room that has no chimney should be looked upon with extreme suspicion by all who love health, and it is not good to use such rooms as bedrooms if this can possibly be avoided.

A Fault in the Factory Laws that Must be Attended to

If we are sensitive to draughts, it is not difficult to remember that the draughts in a room run from the window to the fireplace, and from the door to the fireplace, as a rule. These routes can be avoided if one fears lumbago or has an unprotected scalp.

The mere size of a room is of little importance if there be no ventilation. There is all the difference in the world between cubic feet of space and cubic feet of air, though, unfortunately, the factory laws recognise the one but not the other. If the cubic feet of space do not have their content of air sufficiently rapidly replaced, one is no better off, after a short time, in a big room than in a small room. The largest bedrooms of a palace are not nearly large enough for the needs of a single sleeper throughout the night if the air be not changed.

This is a most important matter for the public health officer and the hygienic legislator, but it also concerns us here in one way. Though the size of rooms or public buildings constantly leads us to suppose that ventilation is less necessary, and though that is simply not the case, yet size has one advantage. It does at least mean that the ever-necessary ventilation may occur with much less need for draughts. Obviously, to ventilate, say, a tunnel or drain-pipe will involve more draught than to ventilate the Albert Hall, badly as that needs to be—and is—ventilated. Therefore, while not relaxing the policy of the open window—it is better to be a "fresh-air fiend" than a "foul-air fiend"—one should try to keep one's rooms as large as possible, by an exceedingly simple device, which also greatly serves cleanliness, diminishes dust, and thus, in these ways also, serves the cause of pure air.

The Folly of Keeping Air out of a House by Useless Furniture

This device is simply the avoidance of all kinds of unnecessary and useless furniture. After all, there are many other ways in which one can demonstrate, or simulate, the possession of ample means, and this is a particularly foolish one. People who overload their rooms with furniture deliberately make their rooms smaller, for they necessarily reduce the capacity of the room. Those who have not made the measurements would be astonished to realise what proportion of the cubic capacity of an over-furnished or even a moderately furnished room is obliterated by furniture. The air that enters is necessarily restricted in its course, perhaps has no choice but to make a narrow dash for the fireplace from the window, and then we complain that the room is draughty if the windows are opened. Add to this the effect of dust and dirt, and the number of dark places, and we can soon realise why unused drawing-rooms, and show rooms in general, are so unpleasing to live in, when the rare attempt is made, and tend soon to become entirely useless—except as breeding-grounds for infection.

The good housewife is a great enemy of dirt and infection, and her passion for cleanliness is certainly a cardinal part of godliness, if by godliness we mean the religion of health and happiness and usefulness for self and others. But she is tempted, as we all are, to make a show, and here she defeats her own ends. She likes things sweet and clean and wholesome, and she hates dust and dirt. If she would only carry these principles out thoroughly, she would avoid a great many things which she prides herself upon—her unused show-room, her unnecessary furniture, her white curtains—which little dispose her toward open windows—and all manner of hangings and rugs and what not which make for darkness, collect dust, impede ventilation, and make her life a burden, besides keeping her far too much from pursuing the best policy of all from every point of view that matters in the long run.

That best policy is the policy of the open door. When all is said and done, and when we have made our homes as hygienic—and beautiful and distinguished—as we can, the open air remains unrivalled. We should learn to work in it, play in it, eat in it, be lazy in it, sleep in it, far more than we do in this country, our much abused climate notwithstanding. The "open air schools" which have appeared in the last few years, and done such wonders already, presage a revolution in our national practice, and the general adoption, not as a fad, but as common sense, of the policy of the open door.

FINDING HEALTH IN THE SUN ON THE SHORES OF LAKE GENEVA

CAMBRIDGE—THE PICTURESQUE HOME OF SCIENTIFIC LEARNING IN ENGLAND

Cambridge has long been the centre of English science, and for the last fourteen years many of the best men of science in every civilised country have been attracted to the famous Cavendish Laboratory, where Sir J. J. Thomson has revolutionised the fundamental science of the structure of matter.

NEW FIELDS OF KNOWLEDGE

A Talk with the Successor to Sir Isaac Newton, whose Discoveries may Increase the Powers of Mankind

THE MAN WHO CHANGED THE WORLD'S IDEAS

For the last fourteen years many of the best men of science in every civilised country have been attracted to the Cavendish Laboratory at Cambridge. They have come to study under a Manchester man, Sir J. J. Thomson, who has entirely revolutionised the fundamental science of the structure of matter. I remember speaking to a French physicist early in 1898, a few months after Professor Thomson had lectured at the Royal Institution.

"If you know nothing about physical science," said my friend, "you are in a better position than I am, who have given my life to it. For you have nothing now to unlearn, and you can start without a handicap."

So tremendous was the change of ideas produced by Sir J. J. Thomson's discoveries that men of science had practically to go to school again and learn afresh the elements of physical knowledge. This was why English and Colonial and foreign students began to crowd into the Cavendish Laboratory. At the present day nearly every professor of physics in America is a pupil of Thomson's; the chief physicist in France is a Cavendish man; and so are many of the best of the younger men in Europe.

The laboratory was built in 1874 by the Duke of Devonshire, a relative of the famous man of science Henry Cavendish. Clerk Maxwell, who developed many of Faraday's ideas on electricity, was the first Cavendish professor of experimental physics. He was succeeded by Lord Rayleigh, the discoverer of argon; and when Rayleigh retired, in 1884, Sir J. J. Thomson was elected to the professorship. Thomson was then only twenty-eight years of age, and his appointment was regarded as a scandal. "Things have come to a pretty pass in the University," a well-known Cambridge don then said, "when a mere boy is made a professor."

But the men who were responsible for the election of "J. J."—to refer to Sir Joseph by the abbreviation now used over all the world—knew the worth of the young man whom they had appointed. Born near Manchester in 1855, he had studied at Owens College under Balfour Stewart, and when he came up to Cambridge, in 1876, he quickly distinguished himself by his talent for mathematics. His first pupils were Mr. Austen Chamberlain and Sir Eldon Gorst. One of these—J. J. would not say which—absolutely loathed mathematics, and his young tutor tried in vain to get him interested in the mistress of all the sciences. But one evening they were playing billiards together; and the professor—who a few months ago delivered at the Royal Institution a delightful lecture on the mathematics of a golf-ball—combined science and play with his recalcitrant pupil. For he showed him how the action of a billiard-ball was determined by mathematical laws, and the undergraduate at once became passionately interested in the science.

Sir Joseph's charmingly human qualities have made him as great as a teacher as he is as a discoverer. Instead of working alone at the laboratory, he invites his students to collaborate with him. They thus receive a magnificent training. Already one of them, Professor Rutherford, of Manchester University, is as famous as his master, and his laboratory is now a school of research, which looks as if it may eclipse the Cavendish. Three times in seven years the Cavendish has produced workers who have won the Nobel Prize in science: their names are Lord Rayleigh, Sir J. J. Thomson, and Professor Rutherford.

The laboratory at Cambridge has grown into a large and important building. The

first extension was opened in 1896, and the second in 1908. The cost was partly defrayed by "J. J.," who gave £4,000 which he had saved out of the students' fees paid to him; and £5,000 was given by Lord Rayleigh out of his Nobel Prize. The building is in the late Gothic style, and, except for the new Rayleigh wing, which retains much of its pristine whiteness of stone, the laboratory now looks as old and mediæval from the outside as the most ancient of Cambridge colleges. The interior, however, is strangely modern. One large room is as unpoetic as a factory. Even the best of theories is regarded as of secondary importance. Much of the work of the laboratory thus depends on the very highest inventive skill, for it is necessary constantly to devise instruments for doing something which no man has yet done.

A few days ago I went to the laboratory to ask Sir J. J. Thomson a question arising from one of his recent lectures. He had pointed out that we needed more science in practical affairs, and he gave as an instance the heavy cost of producing light by the means now used. We spend probably about twenty million pounds a year in

SIR J. J. THOMSON AT WORK IN THE FAMOUS CAVENDISH LABORATORY, CAMBRIDGE

Indeed it *is* a factory, full of whirling wheels, lathes, and busy mechanics. Most of the instruments used in the laboratory are made in this workshop. Many of them are strange and intricate inventions, designed by Sir J. J. Thomson and his fellow-workers; and two skilled instrument-makers are constantly employed in building novel machines.

There is enough practical inventive genius in the laboratory to start many new industries, but it is all devoted to the search of pure science. It is the object of experimental physics to discover new things by means of actual experiment. lighting our streets, our buildings, and our homes, and of this sum *about eighteen million pounds is wasted* in producing heat. All the artificial light we manufacture might cost only about two hundred thousand pounds if we had a practical luminescent lamp in which energy was used in creating a heatless light. The fire-fly and the glow-worm are able to produce light without heat; and so can Sir J. J. Thomson, to some extent, by means of a tube emptied of air and lighted with an electric current, and a rarefied gas. This tube is generally called a cathode tube, and the rays it produces are called cathode rays. I wanted to ask Sir Joseph if it was

metallic surface is the worst of all radiators likely that by this means a cheap, practical, and heatless light could soon be produced.

It was lunch-time when I entered the laboratory, and there was nobody about the building, and I walked downstairs into the underground rooms without seeing anybody. At last I saw in the corner of one of the vaults a middle-aged man, carelessly dressed, and looking like one of the workshop staff, sitting under a window. He was examining some photographic plates, and making calculations on a piece of paper. So absorbed was he that he did not notice me even when I approached the table, though my footsteps echoed in an alarming way through the long vaults.

However, I knew it was "J. J.," and I stood silent for at least a quarter of an hour; naturally, I did not want to break in on his work. So I merely watched him. He looks somewhat older than he really is, for his face is now deeply lined and worn with thought. He is short-sighted, but instead of using his spectacles he pushed them on his forehead. When one's eyes are short-sighted they magnify at a short distance, and I could see that Sir Joseph was using his eyes as microscopes in examining the photographic plates. Suddenly he started up, his face brightening, and he exclaimed aloud:

"One, seven! That is very good!"

Then I guessed what he was working at. Some months ago he gave a lecture at the Royal Institution which provoked the admiration and concern of every man of science throughout the world. Employing the wonderful vacuum tube with which he had made his early discoveries, he recently found out a new way of analysing elements, and in a short time he was able to obtain on a photographic plate the actual evidence of hundreds of new substances. Men are busy in every important laboratory repeating his experiments, and it is now beyond dispute that he is revolutionising the science of chemistry, just as he revolutionised the science of physics.

THE CAVENDISH LABORATORY, CAMBRIDGE
one of the most famous centres of scientific research in the world, where Professor J. J. Thomson is attempting to solve the mystery of gravitation.

His explanation gave me the opportunity of introducing myself. "One, seven" meant 1·7, which was the atomic weight of the new substance he had just traced; and I asked him if he had found any more substances with the weight of 1·5 — the lowest figure, after that of hydrogen, which he had given in his address. He looked up, with a smile, and answered me, and gave me a stool to sit on, and at once engaged in conversation.

Here, so far as I can remember it, is the substance of our talk.

"If I woke up one morning," said Sir Joseph J. Thomson, "and found that the earth had swung out of her course, and the sun did not rise, I should be less amazed than I was over the discovery that the atom was breaking up. A disturbance of the earth might be a local accident in the solar system; the breaking up of the atom meant that our view of the foundation of the entire universe had been suddenly overturned."

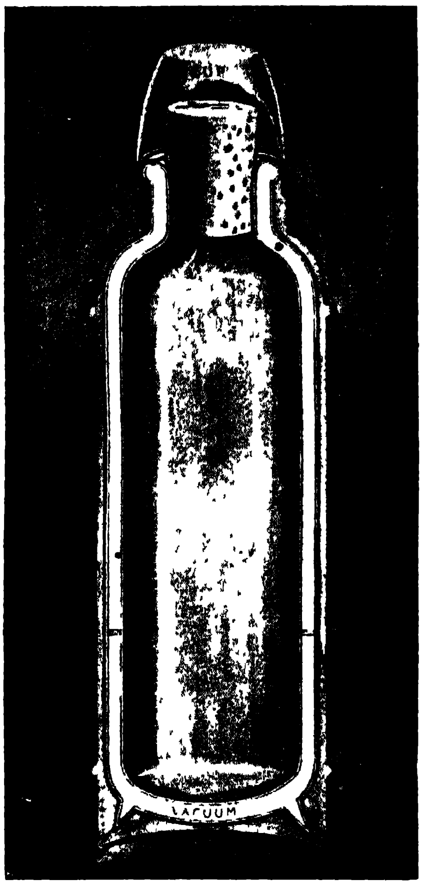
He was not referring to his own work—he will never do that unless under compulsion—but to the discoveries in regard to radium in which his pupil Professor Rutherford took so important a part. His words reminded me of Rutherford's suggestion, that if a proper detonator could be discovered, a wave of atomic explosion might be started through all matter which

would transmute the whole mass of the globe, and leave but a wrack of light gas behind. The suggestion was only put forward in play, but it shows what a terrific source of power man may gain in the future from the new knowledge born in the Cavendish Laboratory. We are only waiting now for a man of science to discover the means of slowly drawing on the energy stored up and enclosed in every atom of matter. Hydrogen, for example, is one of the lightest elements; it possesses a very little fund of force when compared with radium. A litre of hydrogen weighs less than a gram, or something under 15 grains. "Yet," Sir Joseph pointed out, "there is more than seven times the heat of five tons of coal in the energy stored up in a single gram of hydrogen." I asked him if any progress had yet been achieved in making the electric energy in the atom available for use.

"No," he replied; "we have made experiments here for some years—just as other men of science have done in other laboratories—but nothing has been found out. It is absolutely impossible to foretell anything about the matter. At present the thing seems impossible—but it may be done to-morrow—it may be done a thousand years hence—man may perish off the earth, and it may never be done."

Then I brought up the question about producing light without heat, but here again practical invention has still to wait on science. "There is neon, the new gas in the air, discovered by Sir William Ramsay," said Sir J. J. Thomson, "which produces a clear and beautiful radiance, but it is so rare and so costly to extract that it is a light for millionaires. We must be content at present with an electric lamp with the new wire-drawn filament."

He said, however, that if the colour of the mercury lamp could be improved, that would be by far the best light-giver. It is created in a cathode tube containing vaporised mercury.



WHY A THERMOS KEEPS THINGS HOT
The Thermos flask enables us to keep food or liquid hot or cold for twenty-four hours. It is made of two very thin glass bottles, one within the other, and the surfaces of these bottles, forming the "wall" of the vacuum, are silvered. The air between these silvered surfaces is exhausted, and all these conditions prevent the contents of the flask losing their heat.

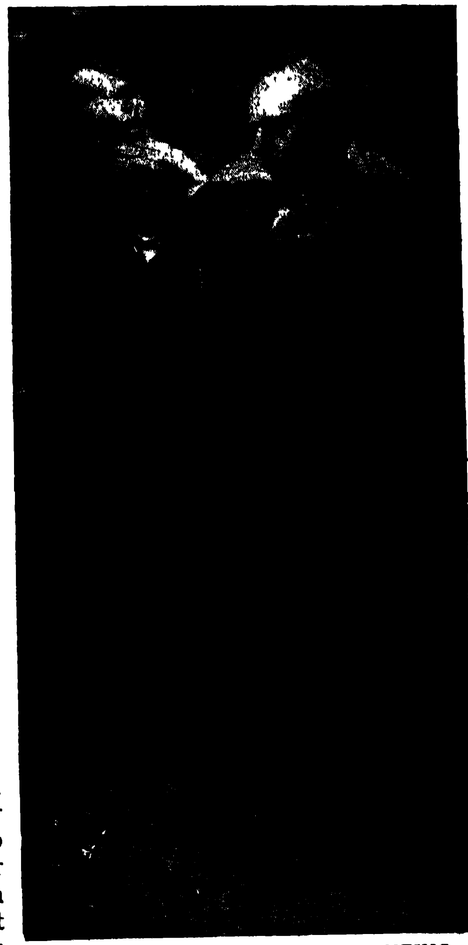
Then the talk turned on the connection between science and industry. It is a lamentable state of things that much of the fine scientific work done in Great Britain has been neglected by our manufacturers, though it has been seized upon abroad, and made into the foundation of important new industries. Sir J. J. Thomson adduced the recent instance of the Thermos flask. In order to make the vacuum in his tubes as perfect as possible, he employs liquid air. If kept in an open vessel, liquid air is like water in a saucepan boiling over a fire; and the trouble is that it cannot be retained in a closed vessel, for its vapour pressure becomes enormously great as heat enters from surrounding objects and the temperature rises. At ordinary temperatures no vessel can withstand the internal pressure of liquid air. Thus experiments with liquid air were not practicable until Sir James Dewar invented the double flask, now known everywhere to all men of science as the Dewar vessel.

There are three ways in which heat passes from one place to another—by conduction, when heat flows from one part of the body to another, or from two bodies in contact; by convection, when air or water, heated by contact with a hot body, rises through the colder fluid around it, carrying heat with it; and by radiation, when heat passes directly from one body to another, as from the sun to the earth, without warming the the intervening medium. The effects of these three modes of transference of heat are reduced to a minimum by the Dewar vessel. In his first invention Sir James Dewar made a double-walled glass tube, and exhausted the air between the two walls of glass. This arrangement so lessened the transference of heat that when liquid air was placed within the inner glass it evaporated at only one-fifth of the ordinary rate. An additional device completed the invention. A polished

metallic surface is the worst of all radiators and the worst absorber of radiation, and Sir James Dewar coated the inner wall of his vacuum vessel with a film of silver or mercury. By this means he reduced the evaporation of liquid air to a sixth part. The combined results of the vacuum and the silvering therefore reduced the rate of loss of liquid air to the thirtieth part of the amount lost in an open vessel. Until the invention of the Dewar vessel, liquid air could not be kept for any length of time, and liquid hydrogen could not be collected at all. It enabled Sir James Dewar to liquefy hydrogen and display it at his lectures at the Royal Institution.

Now, these lectures excited popular attention; they were reported in all the principal newspapers, and the wonders of liquid air became a topic of general discourse. Explanations of the invention of the Dewar vessel were common, and yet there was not a single man in Great Britain interested in its industrial uses.

"Although the discovery was made in England,'' said Sir Joseph Thomson, "no English manufacturer was intelligent enough to take it up, but left it to another nation to make it the basis of an important trade. The Thermos flask is only an application of what has been well known for some years to every man of science as the Dewar vessel."



SIR JAMES DEWAR EXPERIMENTING

The double-flask, invented by Sir James Dewar, and known to all men of science as the Dewar vessel, is a double-walled glass tube with the air removed from between the walls. It was the forerunner of the Thermos flask. Although the Dewar vessel was known to English men of science for years, it was left to another nation to give this British idea a great commercial value.

Portrait by Messrs. Tradelle & Young

The great scientific centres of England are like deep lakes lying in a land which is perishing for want of water. There is no irrigation work, so to speak, between our scientific centres and our centres of industry.

"Things are certainly improving now," said Sir Joseph, "but Englishmen still remain very lazy in mind. Perhaps our chief manufacturers are suffering from too much wealth. The business descends from father to son, leaving the son richer than the father, with the result that he is too well satisfied with his inheritance to use his intelligence in improving it. I know one firm in America that spends about twenty thousand pounds a year on scientific research. And it must pay. I have never heard of an industrial firm going back to the old way after having engaged a man of science to direct its work. German manufacturers and American captains of industry make more use of their men of science than the English do; they consult them in serious difficulties and on every problem of importance."

Sir J. J. Thomson, however, said that he must confess that he is not chiefly interested in the applications of science. That is not his province. He has more joy in finding knowledge than in making any commercial use of it; and in order to devote himself entirely to the search after pure knowledge, he is bound to leave to others the profit of making use of scientific discoveries. Lessing long since said that if God offered him the whole truth in one hand, and the search for truth in the other hand, he would take the search for truth.

"That is it," said the professor. "I dare say if all I am searching after were in a textbook, I should lose interest in it. It is the spirit of the chase that leads us on. The modern man of science has in him a good deal of the primitive hunter."

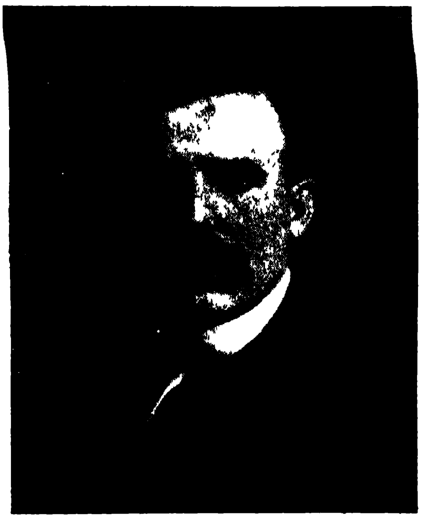
This disinterestedness of the man of science is often a great advantage to the practical inventors who follow—afar off—down the trail that he blazes in new regions of knowledge. It is very doubtful, for instance, if wireless telegraphy would so swiftly have become a general success if the

AN INVENTOR OF THE EARLY WORLD

In this picture, Lord Leighton depicted Dædalus making ready, with his son Icarus, for their flight from Crete. Though the story of Dædalus is mythical, the recent discoveries of wonderful palaces prove that there must have been a master-craftsman in Crete, contemporary with Egypt in its greatness, and it is supposed that ancient civilisation owed to Dædalus the invention of the wedge, the axe, the sails of ships, and other implements.

little band of men who first experimented with electrical waves had patented every discovery they made. The first magnetic detector was used by Professor Rutherford in the Cavendish Laboratory. Marconi now employs, I fancy, a similar detector, but I do not know if Professor Rutherford receives any patent royalties. As a rule, men of science are not concerned about patent rights; they want to advance, not their private fortunes, but the knowledge and the general welfare of the race.

Sir J. J. Thomson took up, early in his career as a physicist, the apparently trivial problem of sending a current of electricity through a gas. He worked on it, with little results of large importance, from 1883 to 1897. He was very near success in 1894. But now the study of the passage of electricity through gases has led to new ideas of matter and electricity. It has brought about the development of the new theory of moving bodies; it has produced the discoveries of Röntgen rays and radio-active substances. Sir Joseph Thomson's discovery seems to have been as great a surprise to him as it was to everybody else. He thought that when a gas became charged with electricity it would be seen that the electric charge was carried on very small particles of gas. He reckoned that the particle would be very minute, and that a molecule of the gas would be split up into electrified atoms. The experiment was made with a certain kind of glass tube, like that with which Professor Röntgen produced the wonderful Röntgen rays. Across the glass tube Sir J. J. Thomson sent a ray formed, he thought, of atoms of gas charged with negative electricity. On each side of the tube were placed electro-magnets. When these magnets were working, they deflected the ray—dragging it out of its straight course through the tube, somewhat as an ordinary magnet would interfere with the swing of a small piece of iron hung and swung fairly close to it.



PROFESSOR RUTHERFORD
Discovered the magnetic detector which helps to make wireless telegraphy possible
Photograph by Maull & Fox

"My idea," he said, "was that some of the molecules were split into two atoms, one of which was positively electrified, and the other negatively electrified. It was some time before I had any suspicion that the rays were anything but charged atoms. My first doubts arose when I measured the extent to which the rays were deflected by a magnet. The deflections were far greater than if the particles had a mass approaching that of hydrogen atoms—the smallest mass then known."

The particles were, in fact, afterwards measured, and it was found that they were about a thousand times smaller than the hydrogen atom. That, perhaps, will not convey any clear idea of their actual size, so let us use an image. Suppose a drop of water were magnified to the size of the earth. It would then be possible to distinguish the molecules of which it was composed. The molecule is made up of atoms. Now suppose, again, that we could magnify the atom to the size of a large room, then the particles which Sir J. J. Thomson discovered would look like specks of dust spinning inside the room. The particles are called corpuscles by Sir Joseph, and other names by other men of science.

The professor has a fondness for the term "corpuscles," because it was used by Sir Isaac Newton in a theory of light which was afterwards abandoned. Corpuscles are the fundamental stuff of which all matter is composed. They consist of a tiny charge of negative electricity; they are pure electricity, with no nucleus of ordinary matter in the middle of them. In the technical phrase, they are electric stresses in the ether, and they seem to get their substance through dragging some of the ether along with them as they move.

Ether is a medium stretching from world to world, and running through every form of matter. You would think, then, that it would be very much lighter than anything we know; but, as a matter of fact, the ether attached to a corpuscle is reckoned by Sir J. J. Thomson to be 2000 million times heavier than lead! Matter is composed of holes in the ether. At least, that is the impression I got when Sir Joseph Thomson was trying to make me understand the subject. I gave it up when I learnt that a

corpuscle increases its mass—that is to say, the ether attracted to it—when it moves at the same velocity as light. All the firmament of heaven and the furniture of the earth seemed to me to be turning into a ghostly phantasmagoria of frail whirls of electricity, and we turned to the structure of the atom.

"Suppose we take a number of corks," he said, using an old illustration, "and thrust through the middle of each of them a magnetic needle, with its negative pole outwards. If these corks float together on the surface of the water, they repel each other. That is what the corpuscles do, because they are all charges of negative electricity. If, however, we were to place a powerful magnet above the corks, with its positive pole turned to their negative poles, it would attract all the corks. They would be drawn towards the common centre by the big magnet above them, and at the same time they would be repelled from the centre by their mutual repulsion. Under the influences of the two forces they would settle down into a stable arrangement. The arrangement would vary according to the number of the corks. Now, an atom consists not only of negative corpuscles, but also of a larger charge of positive electricity, which we call the positive electron. This acts in regard to the corpuscles in somewhat the same way as the positive pole of the big magnet in regard to the negative pole of the corks."

The Discovery of the Electron which Illumines the Problem of Matter

This positive electron is another of Sir J. J. Thomson's remarkable discoveries. It is about a thousand times larger than the corpuscles, and about equal in size to the atom of hydrogen. Unlike the corks in the water, the corpuscles are in continual and swift motion. The atom is a sort of little solar system. The great positive electron is like the sun, and the corpuscles are like the smaller planets, and they revolve very rapidly in their orbits. The atom does not usually split up, because the forces of repulsion between the corpuscles are slightly outbalanced by the force of attraction between the positive electric charge of the electron and the negative charges of the corpuscles.

This new and wonderful view of the structure of the atom illuminates the greatest problem in modern physics—the problem of the strange rays emitted by radium and other radio-active matter. Radium, as is now well known, is an element which is slowly discomposing into lead. The rays are now regarded as portions of an atom ejected as a result of the collapse of the atomic structure. The instability which brings about the explosion is supposed to be due to a slow but constant loss of energy. This loss of energy falls on the corpuscles, which are whirling in closed orbits within the atom. When the speed with which a corpuscle is whirling is diminished, the extent of its orbit is also lessened; so there is a sudden change in the structure of the atom. The tiny universe is destroyed, and arranged in a different way, and some corpuscles are thrown out in the form of rays, together with other electrical discharges. This constitutes radio-activity.

Do the Common Elements Give Off Rays as Rarer Elements Do?

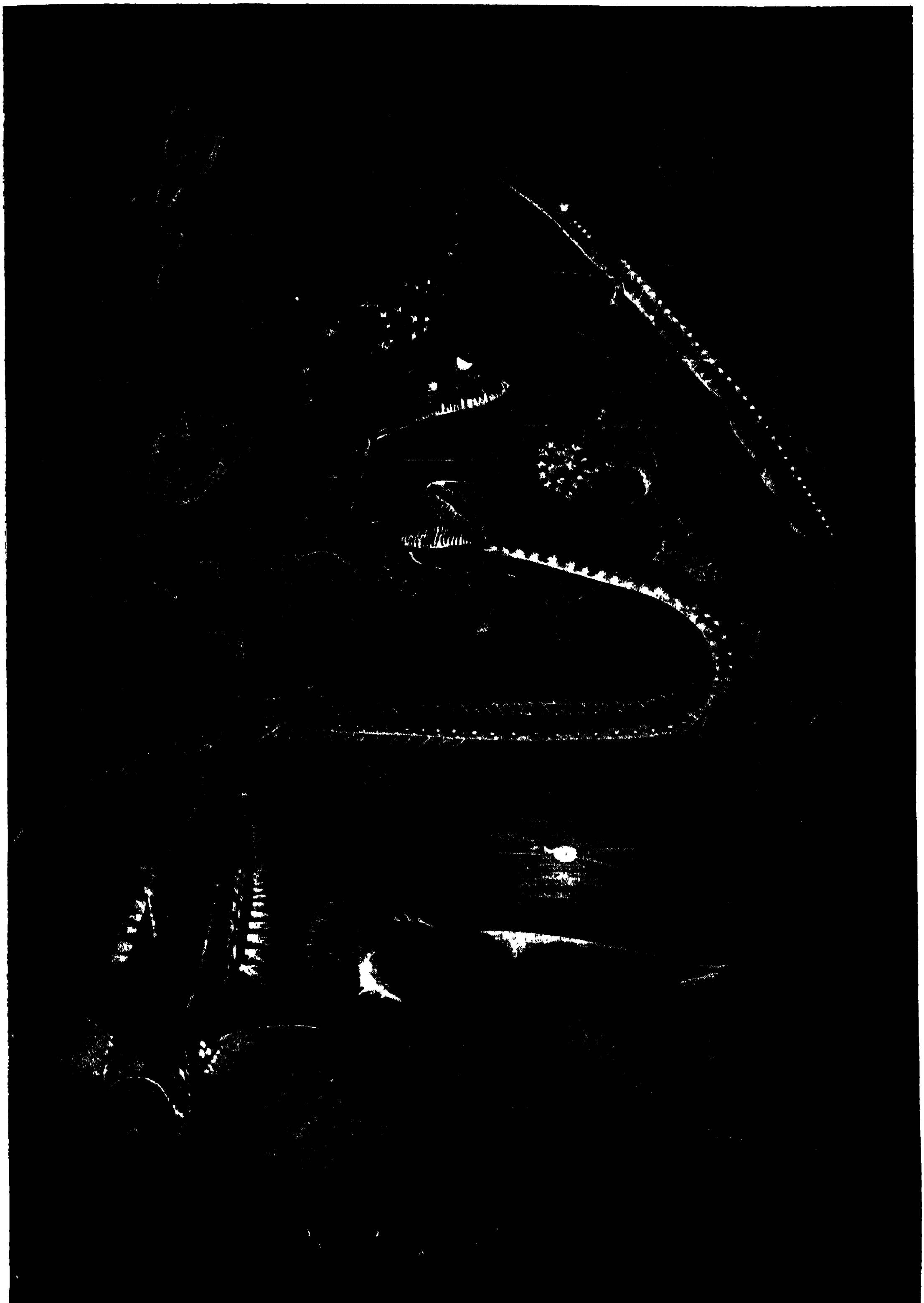
It has been thought that if common elements were studied with sufficiently fine instruments, they would also be found to be emitting rays. For some years the workers in the Cavendish Laboratory held to the view that every kind of matter gave out rays, and many of these rays have been detected. Many other men of science, however, do not agree with the Cavendish view. The trouble is that in a number of metals the ray seems so short-lived that its existence cannot be demonstrated, and in the absence of decisive experiment the matter remains in suspense.

In the meantime Sir J. J. Thomson has gone on exploring new fields of knowledge. Having settled the business of the negative corpuscle, he has attacked the large positive electron. He has not yet found out anything more about it, but he has not given up hope. The last by-product of his researches into the subject has already created a new branch of science. It was on this that he was engaged when I found him.

An Instrument a Million Million Times more Exact than the Spectroscope

Up to last April the spectroscope was the finest instrument of analysis that a chemist possessed. If, after vainly trying all other tests, he wished to know of what some mixed substance was made, he burnt it and converted it into gas, and directed a ray of the gas against a prism of glass. This prism broke the light up into a band of colours streaked with dark lines; and by examining the lines and the colours the chemist was able to tell to some extent of what the burnt substance was composed. Sir J. J. Thomson's instrument is one million million times more exact than the spectroscope. It detects chemical combinations which exist only in that part of a second which compares to a second as a

NATURAL LIGHT IN OCEAN DEPTHS



Millions of money could be saved if men could master the secret of these phosphorescent fishes, which illumine the depths of the ocean with a glow compared to the illumination of a city. These fishes produce light without heat, but most of the energy which men use in making light runs away in heat.

second compares to a year. Thus it shows the steps by which chemical combinations are brought about, and it promises to throw a flood of new light on the ultimate problems of chemistry.

The marvellous cathode tube which has been Sir J. J. Thomson's chief instrument of research for the last nineteen years is shown on page 463. The glass part of the tube consists of two tubes connected by a glass globe. It is fixed high upon a stand, and attached to it are an air-pump and other ingenious devices for maintaining a high vacuum in the tube. On each side of the tube are electro-magnets, and inside the tube is a curious aluminium rod. This rod is the cathode. When a current of electricity is sent into the tube at a point called the anode, it strikes against an opposite point, which is termed the cathode. When the tube through which the electricity passes contains some rarefied gas, a cathode ray is produced; and it was through examining these cathode rays that Sir J. J. Thomson found that the gas had been split up into minute corpuscles of negative electricity. When the cathode ray strikes against the glass of the tube it is changed into the X-ray that Röntgen discovered.

New Forms of Matter Discovered at the very Moment of their Birth

In ordinary cathode rays, there is only negative electricity. In order to examine the particles of gas carried on a charge of *positive* electricity, the cathode has to be altered. A tiny channel is bored through it, and the ray that comes through this channel is called the positive ray. The ray is made up of electrified particles of the gas which has been admitted into the tube. It strikes against a photographic plate at the far end of the tube and imprints on the plate a curious lot of dark curves. These curves are the new positive ray spectra, and by means of them it is easy to calculate the weight of the substances through which the current of electricity has passed. It appears that the commonest gas can be broken up and transformed into strange new substances by passing a current of electricity through it. A large unknown and important field of knowledge has thus suddenly been opened up, and Sir J. J. Thomson is now busy devising finer instruments for analysing the numerous new forms of matter which he has been able to discover at the very moment of their birth.

Sir Joseph told me that inspiration often comes to him when he is not thinking about the matter. "It is born of hard work," he said to me; "but somehow, when the conscious intellect has done its best and got no result, a part of the mind seems to go on working without our knowing it."

This part of the mind that goes on working out an idea when the intellect is at rest is called the subliminal consciousness. It is on its richness and powers that the genius of a man seems to depend. Perhaps "J. J.'s" subliminal consciousness will one day enable him to solve the supreme mystery in physical science.

The Hope that the Supreme Mystery of Gravitation may be Solved

Two hundred years have gone since Newton formed a theory of the universal attraction of material bodies, and gave us a sublime view of the universe governed by one tremendous law. Since that time, however, gravitation has remained totally unconnected with any other branch of knowledge, and no one has been able to throw any light whatever on it. All bodies attract one another in proportion to their masses, and inversely to the square of their distances. That is all we knew about gravitation until Sir J. J. Thomson's experiments definitely proved that matter was a form of electricity.

For fourteen years and more Sir Joseph has been puzzling over the mystery of gravity, and he is now not without some hope of solving it. This is how he explained to me the new theory of gravitation.

"Every atom consists of a positive charge of electricity—the positive electron, and a varying number of charges of negative electricity—the corpuscles. There is probably a little balance of attractive electrical force left over in each atom, and perhaps this little balance of attraction is the explanation of the mystery of gravitation."

Will the Tremendous Problem of Gravitation be Solved?

The point is difficult to convey to anyone unacquainted with the principles of electricity, but we shall all understand something about it if Professor Thomson succeeds in an experiment. He has for years, he confesses, been dreaming of making this experiment. There is some reason for thinking that, though the negative corpuscle is a thousand times smaller than the positive electron, it is equal in weight; and "J. J." intends to try to weigh them. The experiment is enormously difficult, and everybody else in the laboratory seems to think that it is impossible; and even the professor himself does not yet see clearly the way to carry it out. But this is how he will

probably attempt it. He will use a cathode tube, and send a positive electron along a line a metre in length. Then he will send a negative corpuscle along the same line. If his theory is correct, the force of gravitation will make the positive electron incline downwards somewhat less than a thousandth of an inch in the distance of a mile, while the drop for a negative corpuscle, under the influence of gravity, will be one thousand times as great—one ten-thousandth of a millimetre in a distance of one metre.

To revert to the image already used: if a drop of water were magnified to the size of the earth so that the molecules could be seen, the distance between the line taken by the positive electron and the curve made by the negative corpuscle would be about as large as that between two molecules. It is impossible to imagine an instrument being invented to measure so marvellously small a difference as this, especially in an electrical experiment where there are so many chances of disturbances being created from the outside, each of which would more than counteract the effect of gravity on the little negative corpuscle. One well-known Cambridge man has calculated that a vacuum tube about a hundred feet long would be necessary to make the experiment in a practical way, and such a tube probably could never be made.

Sir J. J. Thomson, however, thinks that he can do it over the distance of a metre—which is little more than a yard. He has discovered a means of winding a positive or negative ray round and round a straight line, in close coils, so that the ray at last somewhat resembles a tightly wound spring. He does this by catching hold of the ray with a magnet, and winding it round and round in closely packed rings. By using these rings he hopes to be able so to economise space as to conduct the experiment on gravity inside a cathode tube of little more than the ordinary size. The difficulty with outside disturbances will still be very great, for naturally only an exceedingly small current of electricity will be used. It may be years before Sir J. J. Thomson gets over these difficulties and attempts the experiment, But if the experiment is made, and is successful, there will be only one great secret left for man still to dream over—the secret of the origin and qualities of life. The material universe will be an open book.

THE CHIEF INSTRUMENT OF PROFESSOR THOMSON'S RESEARCH AT CAMBRIDGE

Sir J. J. Thomson, who has been called the successor of Sir Isaac Newton, not without justification has drawn the attention of scientific men all over the world to his famous laboratory at Cambridge. Professor Thomson's discoveries have changed the world's ideas about matter.

DRIVEN FROM HIS PLACE IN THE SUN

It is a terrible truth that in this proud country, where child life is supposed to be precious, 50,000 little boys not over fifteen years old are sent down our mines every day. Between 6000 and 7000 of them are only thirteen, and about eighty are killed every year. It is hoped Parliament will soon be called upon to save these boys from the life of the mine, and bring them back to their place in the sun.

BRITAIN'S BLACK DIAMONDS

The Great Traffic in the Sunshine of the Ancient World upon which Modern Britain is Based

COAL, THE BURIED TREASURE OF A NATION

The sensational impetus felt by industry and commerce during the last century, an impetus unparalleled in the history of the world, had its origin in new applications of force through the use of machinery. The three principal factors in that epoch-making development have been the perfecting of steel as the prime material for machinery; the working of coal to provide power in the form of heat; and the unexampled response from human invention, as these new instruments of progress came gradually into play.

We have pictured the part taken in this great practical drama by the master-material steel, and we must now show how coal, scarcely known two hundred years ago as one of the world's supreme sources of energy and wealth, has contributed to the industrial revolution, and has placed three nations—Great Britain, the United States, and Germany—far ahead of the rest of the world, in positions that make old-time conquests by arms appear local and paltry.

Doubtless a time will come when the use of coal for power-producing purposes, through its transformation into heat, will be superseded. The earth has greater reservoirs of power than all its accessible coal-beds, and the needs of mankind will stimulate invention till these reservoirs are utilised. Thus such stupendous power as is latent in universal attraction, and seen familiarly in the tides, will be harnessed and controlled. But for the moment coal reigns supreme, as it has reigned for nearly a hundred years, and will reign perhaps for another hundred years. In the main, it provides the strength that moves the world's machinery, as steel provides the material for that machinery. Even when electricity supplies the immediate working power, coal usually takes its part, a stage farther back, in the production of that electricity. This, too, will doubtless be altered; but when coal is no longer the chief agent in the production of power, either in the form of heat or of electricity, an enormous range of uses will remain for its chemical transformations, and this giant, now besmirched and malodorous, will come to be regarded as a fairy magician, whose wand calls forth all the colours, scents, and essences of a cleaner life.

What is coal? The answer is not so simple as the casual observer would expect. We know that coal is "buried sunshine"—the fossil of enormous fern-trees which drank in the sunlight pouring down upon a manless world, and now gives the sunshine back to us in the form of fire; but that is not enough. Large sums of money have been spent on law without a conclusive definition being arrived at, for the word "coal" covers a wide variety of earth-held substances that may be used as fuel. It has no standard chemical composition. Coal is a rock, composed chiefly of carbon, and formed from vegetable matter, capable of being burned as a fuel, and when so burned producing, in varying degrees, heat and light.

The varying composition of coal depends partly on what it was formed of—that is, the nature of its vegetable basis; and partly on where and how it was formed—that is, on such conditions as place, time, pressure, and the influences of heat and of chemical change. This great variety in composition enables coal to be put to a wide range of uses, and prevents any one form of the substance from being regarded as most typical, because most valuable. One kind is best for one purpose and another for another purpose, and excellence in quality is not absolute, but comparative, according to the particular use that is desired.

Broad classifications of the different sorts of coal depend chiefly on the proportion of

THE SCENE AT THE TOP OF A GREAT YORKSHIRE COAL-MINE

This photograph shows the top of a big Yorkshire mine from which hundreds of thousands of tons of coal are brought up every year. To possess a diamond the size of a marble is to have a fortune, yet the diamond is made of the same substance as a piece of coal. But the coal is really more worthy of admiration than the diamond, for to coal we owe our commerce and industry. Without coal there would be no steel, or railways, or machinery, or ocean liners.

carbon each contains. Thus, fuels may be arranged by their carbon-wealth in the following ascending scale: Wood, 50 per cent. of carbon; peat, 52 to 60 per cent.; lignite and brown coal, from 55 to 67 per cent; cannel, from 80 to 85 per cent.; humic or bituminous coal, from 80 to 92 per cent.; anthracite, from 93 to 97 per cent. Above this the substance becomes graphite, or almost pure carbon, and is unburnable. These different kinds of coal, with from 60 to 95 per cent. of carbon, are graded imperceptibly into each other by the conditions under which they have been formed, the central group of the series being the humic or so-called bituminous coal, of which English North-country house-coal is typical.

The Substances in the Earth that Make Up Coal

Besides carbon, coal contains hydrogen, oxygen, nitrogen, sulphur, and other constituents in small proportions, but these associated ingredients decrease as carbon increases. It would be a mistake, however, to regard coal as a substance passing regularly from wood or vegetable debris to peat, from peat to lignite (coal with a woody structure), from lignite to brown coal (with the woody structure obliterated), from brown coal to cannel (coal that lights easily and flares), from the cannel to the humic, and from the humic to the anthracite variety—in which an intrusion of molten rocks has driven off nearly all the volatile elements by its heat. These gradations occur, here and there, under varying conditions of formation, but not as a regularly arranged sequence. The passage from lignite to brown coal may be observed, for instance, in Germany, and from humic to anthracite coal in South Wales, but nowhere has the depositing of the vegetable substance been so ordered in quality, and followed by such pressures, and such proximities of internal heat, as to form in sequence all the newer coals, down to the seams that have been subjected in some places to more drastic chemical changes.

The Qualities of the Various Kinds of Coal Found in the World

It is necessary to take a survey of the coal-seams of the world, and to imagine varying types of vegetation laid down under differing conditions, subject to greater or less stresses, and to incidental rather than universal chemical reactions, if we are to classify truly the various kinds of coal.

Lignites are not found in considerable quantities in Great Britain, but they form the greater part of the output of Austria, and about three per cent. of that of Germany. Cannel is so called because it flames into a torch like a candle. It is bright and smooth, sometimes crackles and splits, produces paraffin, and is excellent for gas-making. Often it occurs in conjunction with humic coal. Humic or bituminous coal varies widely in its composition, grading into brown coal on the one hand, and into anthracite, or stone coal on the other hand. It is the most generally usable variety for steam, gas, and household purposes. The name "bituminous" was given to it because it sometimes "runs," and has a bituminous appéarance, though there is no bitumen in it. It lights readily, whereas anthracite is difficult to light, though giving great heat when started. Anthracite contains so little volatile matter as to be almost smokeless. The coal called "smokeless" supplied by South Wales to the Navy is an anthracite with humic qualities, or a low carbon-power for an anthracite, so that it combines heating capacity with comparatively ready ignition and little smoke.

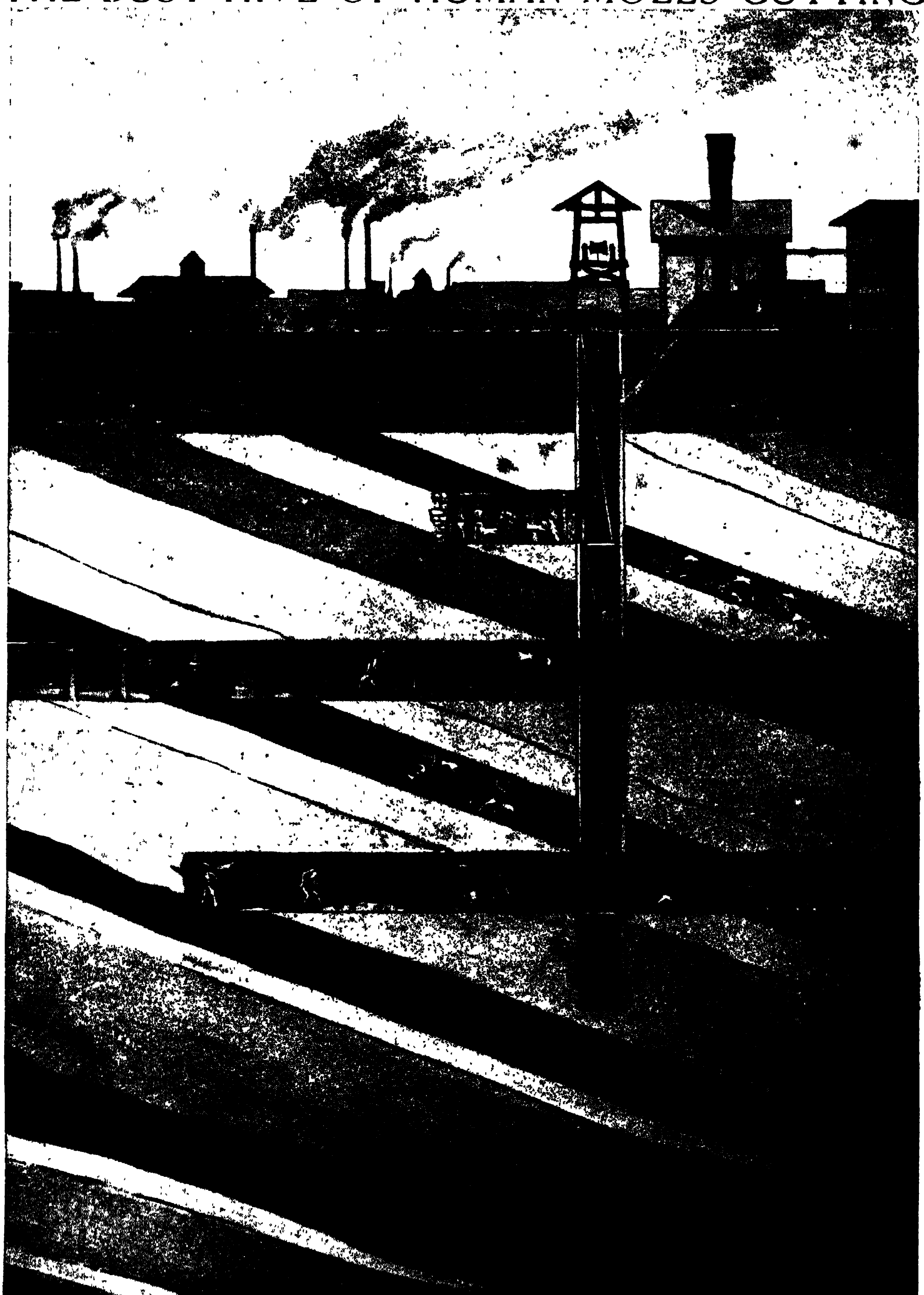
How Coal is Distributed Throughout the World

The earth's coal-beds—laid down with a marvellous regularity in level strata, almost unmixed with casual intrusions of other matter, though the seams, varying in thickness from less than an inch to sixty feet, are much broken by "faults" where they have snapped and dropped—are found associated with, and surrounded by, beds of sandstone, clay, and limestone. Nowhere are they the dominant rocks. The so-called carboniferous system of geology, between the new red sandstone above and the old red sandstone below, is a huge belt of the earth's crust streaked here and there with comparatively slender layers of coal. For example, the richest coal measures in Great Britain, those of South Wales, are 8,000 feet in thickness, and the aggregate of the many coal-seams running through them is only 200 feet, or one-fortieth of the whole.

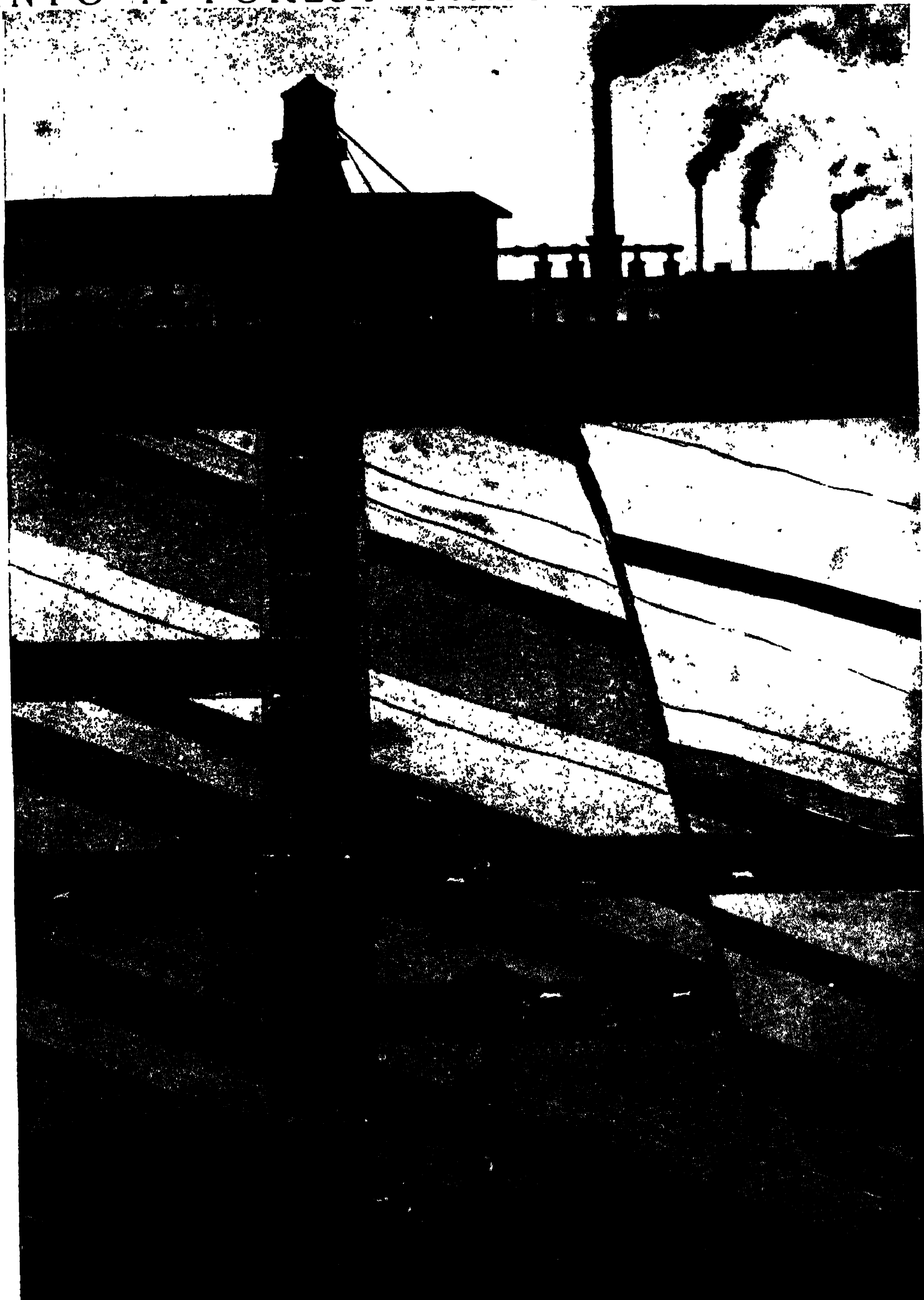
This is an instance of richness in coal; but coal in some of its forms is found, in traces, from its formation going on to-day in lakes, estuaries, swamps, and bogs, down to the Silurian period, which marks, in the far-off past, the margin of its recognisable existence.

Coal is distributed throughout all the continents, but with much irregularity. In Europe it is worked in the United

THE BUSY HIVE OF HUMAN MOLES CUTTING



Here is a picture-diagram of a coal-mine "with the lid off," showing what the pits and workings are really like. The black slanting lines mark the coal-seams, and roadways lead to these from the shafts. A constant circulation of pure air is maintained underground, either by a furnace at the bottom of one shaft, causing warm air to rise, or by a pump at the top, which sucks the bad air out of the mine through



the special ventilating shaft. A quarter of a million cubic feet of air pass through the shafts of some mines every minute. A single pair of shafts will serve thousands of acres of workings. Sometimes an underground passage is a mile long, and one mine near Newcastle has fifty miles of passages —fifty miles of walks, that is, through prehistoric forests which grew before man came on the earth.

Kingdom, Germany, France, Belgium, Austria, Russia, and Spain. In Asia, Japan, India, and China have an increasing trade. Africa has some mines. The coal measures pass by the Malayan Archipelago to Australia and New Zealand, and on to South America, while the United States hold the world's largest supply. The Dominion of Canada has coal in the east and the west, and the Polar regions have a surface coal that allured speculators.

The Source of Modern Power that the Ancient World Knew Nothing About

If we regard fifteen million tons per year as a large aggregate of production, the following countries must be mentioned: The United States, 390 millions; the United Kingdom, 263 millions; Germany, 148; Austria, 49; France, 37; Russia, 25; Belgium, 23; and Japan, 15. India, Canada, and New South Wales follow. These are the returns for the year 1909, issued in 1911.

This enormous output of coal, near all the busy industrial centres of the world, to run mankind's machinery, and the trains and the ships that exchange the productions of every race and climate, is quite a new thing. The ancient world did not know of coal, and had no practical use for it. About 2000 years ago the Britons knew the use of coal, and the Romans learned it from them. The Anglo-Saxons used coal for domestic purposes, and England appears to be the first country in which it is unmistakably mentioned in writing, the Saxon Chronicle being the recording manuscript. England, too, holds the historical record for beginning the working of the mineral—a charter granted in 1259, by Henry III., to the inhabitants of Newcastle to dig coal in their Castle fields. But for hundreds of years after that the use of coal was regarded—in London, at any rate—as a superfluity, an offence, and a danger to the public health, to be prohibited when Parliament was sitting, and taxed at all times.

The Gradual Rise of the Modern Age of Coal Power

The explanation is that there is no need of coal in a country living a simple life, with plenty of wood near at hand, and no large towns. Why should men with toil and danger dig coal from the dark depths of the earth when with less labour they can fell a tree? It was only when the forests were being used up and the great towns were growing that necessity forced men to face recurring calamity and to battle with the ill-understood dangers of the mine—a battle that has been fought steadily ever since, with accumulating difficulties and a growing list of triumphs.

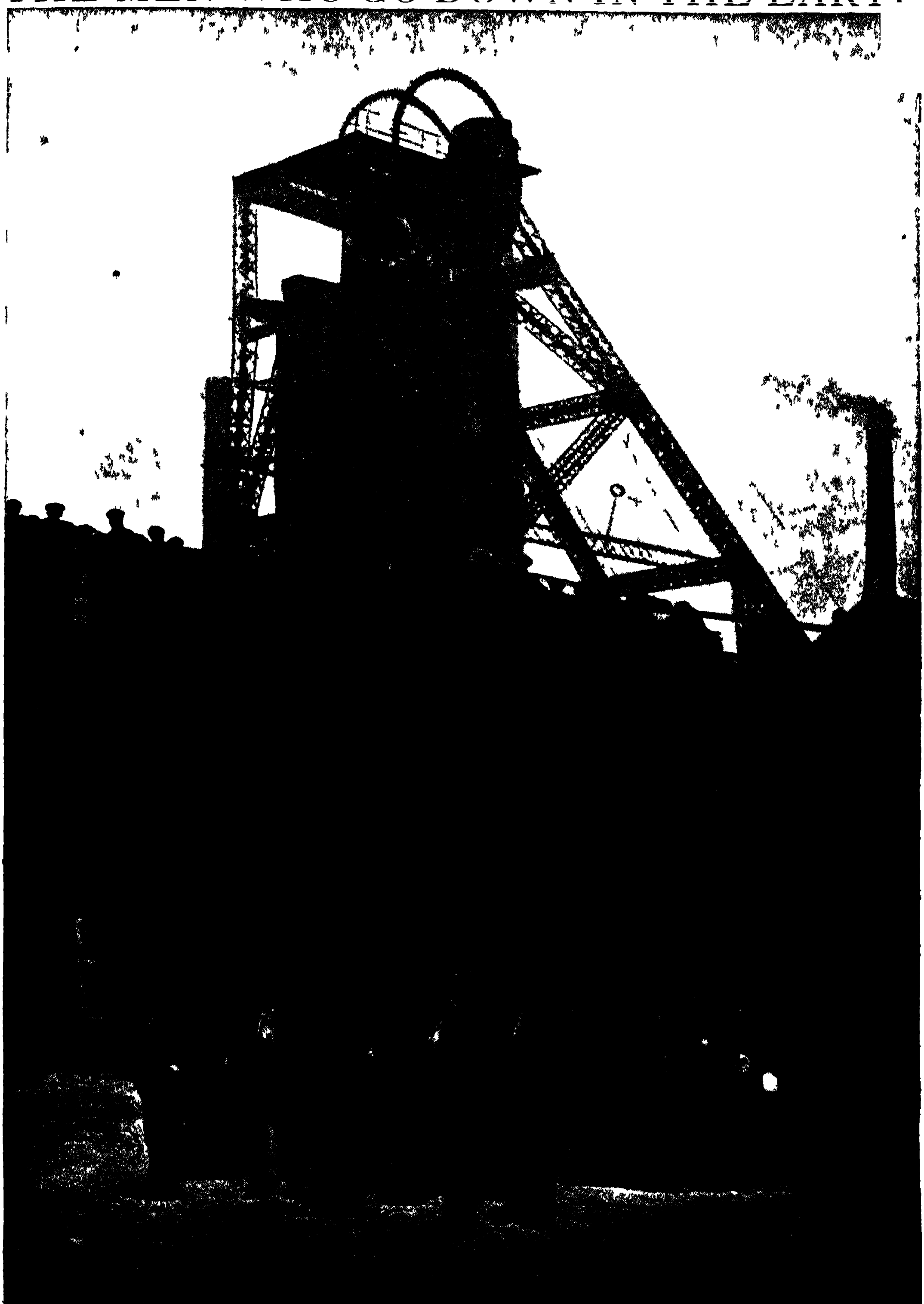
It was the extension of London that made the trade in coal imperative, and by 1605 four hundred ships of small tonnage were engaged in bringing coal from the North. The tax on coal, which had been a prolific source of revenue under the Stuarts, was remitted in the reign of William III. From the middle of the eighteenth century the consumption of coal rapidly increased owing to the use of coke, instead of charcoal, for smelting; and the advent of steam as the power for driving engines, stationary and locomotive, with the use of gas as an illuminant—adopted in London in 1807—introduced the modern era, wherein coal has been the supreme source of industrial energy on the mechanical side, with a wonderful development in more recent times through the chemical utilisation of its by-products.

The Stern Fight between Men and Death in the Mine

Coal, which had lain unappreciated as a dormant resource through countless centuries, began to be a half-banned luxury about three hundred years ago, became a growing necessity two hundred years ago, was realised one of the master materials of the world's progress a hundred years ago, and now is engaging far-seeing minds in anxious speculation as to its duration under the inexorable demands of mechanical industry. It seems as if its swift and furious race might be quickly run in countries like our own, judged in the perspective of historical ages; but however that may be, the conquest of coal will remain one of the most notable chapters of human endeavour.

To-day we accept as a matter of course the smooth running of the stupendous coal trade of our land, except when a blast from the mouth of Death quenches all the life of a mine and devastates the homes of a country-side. Then we sigh, and accept the calamity as a sad recurring certainty. But we do not realise how long and stern the fight with Death in the mine has been; how great, if slow, the victories of human ingenuity, and how comparatively seldom, considering the magnitude of the work, Death finds a loophole for his ready dart.

The history of the getting of coal is a history of its difficulties overcome; and there is no more impressive record of the task of



Nearly a thousand miners have here received their safety lamps, and are just going to the pit head to descend into the mine. There are in the United Kingdom over eight hundred thousand miners and they brought up in 1909 nearly 264 million tons of coal.

understanding Nature and bringing about an accommodation between her laws and the life of man. For, in getting coal, men entered gradually a new sphere of work —the solid crust of the earth—with dangers accumulating at every advance, and each fresh lesson was learnt through ruin and loss of life.

At first coal was quarried, so to speak, horizontally, in a cave-like manner, where it cropped out on the surface, the seam being followed as if through a broad, dipping tunnel. In those times, women were employed to carry the mineral to the outlet on their backs in baskets. The first difficulty encountered was the presence of water, which, through the dip of the strata, accumulated in the workings. When vertical shafts became necessary to reach the lower and more valuable seams, this difficulty was increased, as water-bearing layers were bound to be struck, and the water collected in the bottom of the shaft.

The Deadly Foe in the Mine which Science has not Overcome Even Yet

At first, pumping was introduced by means of a chain of buckets worked by a water-wheel, and then by a windlass turned by horses, but many mines were captured by the waters, and for the moment man was driven back defeated. The tables were turned, however, in 1705, when Thomas Newcomen, a blacksmith of Dartmouth, invented the steam-engine, pumping through atmospheric pressure, that afterwards became known as "The Miners' Friend." By 1712, Newcomen's engine had reached such a state of efficiency that it had begun to master the waters of the flooded mines, and to enable pits to be sunk to deeper levels. So the range of man's kingdom was extended by Newcomen's contrivance for "raising water by fire."

But the deepening of the mines revealed a new danger. Hitherto, water had been the enemy. So plentiful was it in some districts that it produced a quicksand layer through which sinking was impossible, until the soil below and around the bottom of the shaft had been frozen solid to facilitate its removal, after which the orifice was cased with rings of iron tubing. When the mines, however, had passed through the region of damp, and reached a dryer layer, they encountered a far deadlier foe, that even yet has not been finally overcome. They were met by fire, and were temporarily routed. The first recorded explosion occurred in 1705, near Gateshead, and three years later another explosion cost 69 lives. Increasing depth further complicated the problem of ventilation, for, below 50 feet, where atmospheric changes of temperature cease to produce any effect, there is an increase of one degree in temperature for every 60 feet.

With the increase of gases, difficulties of lighting, while work was carried on, were accentuated, and the greater depths of shafts and extent of workings made imperative a change in methods of hauling coal to the bottom of the shaft and raising it to the top. All these difficulties came thronging on the mine managers at once, as soon as coal had been followed towards the hot, foul darkness of the earth's heavily pressed core.

The Fireman whose Business it was to Cause Explosions

While mines were of inconsiderable depth—no deeper than many wells of to-day—gases, of course, collected, though in small quantities, and it became customary to explode them before the miners entered the workings. For this purpose, a "fireman," as he was called, wrapped in fire-resisting blanketing saturated with water, crept forward and caused an explosion by projecting a candle at the end of a long pole. He then flung himself on the ground while the flames passed over him under the roof. This could not last long, and the next step was to tap the gas where a strong escape was found, and pipe it to the surface —an invention of the ingenious Carlisle Spedding, of Whitehaven. He also invented a flint-and-steel revolving machine that gave forth sufficient light to work by in places where candles would have fired the gas, whereas "the spark-emitting wheel played harmless in the sulphurous air." Yet it was by an explosion that Spedding lost his life. His son James made a great step forward towards safety by so arranging the ventilation that the air, in passing from the downcast shaft to the upcast shaft—two shafts being now sunk for each mine—swept through all the workings, and so tended to clear away the gases, instead of being directed only to the part of the mine where the men were working.

The Demand for Coal that Led to the Invention of Railways

The demand for coal continuing to increase enormously, the workings, which for a long time had not been carried more than two hundred yards away from the bottom of the pit, were extended, and sinking to lower beds went on constantly, bringing in the necessity for quicker haulage of the coal through the mine to the bottom of the shaft, and more effective lifting to the

HOW THE MEN GO DOWN THE MINE

The miners go down the pit in a cage like this, which is lowered by a chain or rope worked by an engine. Sometimes the rope alone weighs nearly twenty tons; and some huge cages have three or four storeys. Some pits are nearly four thousand feet deep. It is estimated that England still has nearly 5700 million tons of coal at workable depths, but Sir William Ramsay believes this will be used up in 175 years.

surface. The haulage difficulty led to the invention of railways—wooden railings along the main roads of the pit where horses could draw wheeled tubs. These "rail" ways were also used for conveying the coal in the North of England from the pit-mouths to the waterways for distant transport.

The lifting of the coal up the shaft was first managed by horses working a windlass. When steam was employed for this purpose, it was employed indirectly. Newcomen's engine, or James Watt's improvement of it, were used to raise water, which in its turn worked a water-wheel to raise the coal, a system ended by Watt's later improvements on the steam-engine making it directly usable for lifting loads up the shaft.

The speed of coal-getting was now enormously increased. At first, wicker baskets made of hazel rods were suspended in the shaft from hempen ropes, and it was thought wonderful that 90 tons of coal should be raised in a day from a shallow Newcastle pit. Three hundred tons a day was the largest amount that was ever raised by this primitive system of winding. Now, 3,360 tons have been raised in one day at the Cadeby Main Mine, near Doncaster, from a depth of 763 yards.

How the Coal Came up the Shaft in the Old Days

An early impetus to the swift removal of coal from the mine was given by John Curr, of Sheffield, who substituted cast-iron rails, above and below, for wooden ones, wheeled waggons for the old corves, guides in the shaft to carry steadily a firm cage, and a flat rope that increased the diameter of the drum on which it was wound as the cage neared the top, and thus quickened the pace of ascent. He also was the first to use fixed engines for hauling waggons. It may be said that Curr's improvements in the last quarter of the eighteenth century, and the advancements on them by Hall, a Durham engineer, in the first quarter of the nineteenth century, established broadly the system now in force for raising the coal from the pits, though, of course, improvements have been constantly introduced, with labour-saving arrangements, at every point in the process.

While these measures for ensuring swiftness and economy were being taken, the fight for life in the ever-deepening pits went on. Diluting the escaping gases with a strong ventilating current, and firing small accumulations, proved utterly insufficient to prevent terrible catastrophes; while the steel-mill light, which had been regarded as safe in quite shallow mines, proved fatal under differing circumstances. At the beginning of the nineteenth century seven terrible explosions occurred in a few months, and public discussion respecting systems of ventilation became eager.

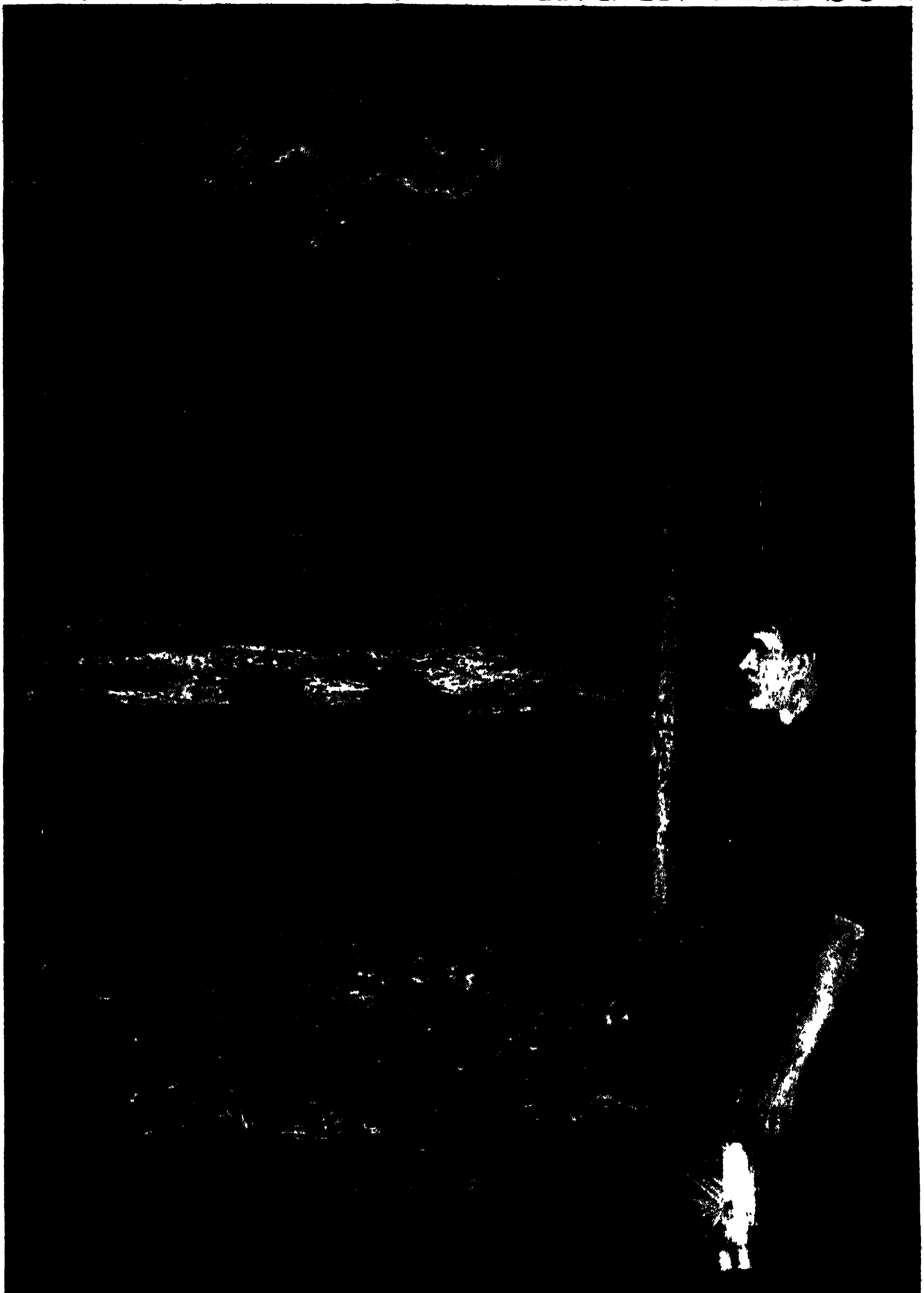
How Sir Humphry Davy Gave the Miner's Lamp to the World

It was clear that the dilution of escaped gases by a current of fresh air was not an adequate remedy, for gases constantly accumulated in foulness till they fired when passing over the furnace at the bottom of the upcast shaft. Great improvements were made in ventilation, particularly by John Buddle, of the Wallsend Colliery, at Newcastle, who introduced the compound system, supplying two streams of fresh air instead of one, and limiting the circuit made by each current; but explosions continued, and it became clear that relief must be sought through preventing the ignition of gases, as the gases themselves could not be entirely cleared away. This was Mr. Buddle's opinion. Under these circumstances, Sir Humphry Davy was asked for his advice, and paid a visit to the North of England, where the facts were placed before him by Mr. Buddle—the most competent colliery manager of his day. "I think I can do something for you," were the modest words with which Sir Humphry closed the interview, and seven weeks later he announced that his experiments had been fortunate beyond his expectations. The result was the discovery of the Davy safety lamp. "We have at last subdued the monster!" was the exclamation of Mr. Buddle when he saw the lamp burning amid gases which it did not fire. Later, when asked why he had not patented his invention, Sir Humphry replied: "I never thought of such a thing. My object was to serve humanity." It was a noble ending for a great crusade.

The Lamp that has Saved Thousands and Thousands of Lives

Davy's lamp is based on the assumption that an explosion will not pass through small apertures, and accordingly he made a wire gauze lamp. It has been found that the gauze must not contain less than 784 apertures to the square inch. Though the invention has been the means of preserving tens of thousands of endangered lives, and cases of apparent failure have often been referable to gross ignorance or wilful carelessness on the part of the users of the lamp, it has been ascertained that immunity from explosion depends on the velocity with which a current

A FOREST ONCE STANDING IN THE SUN

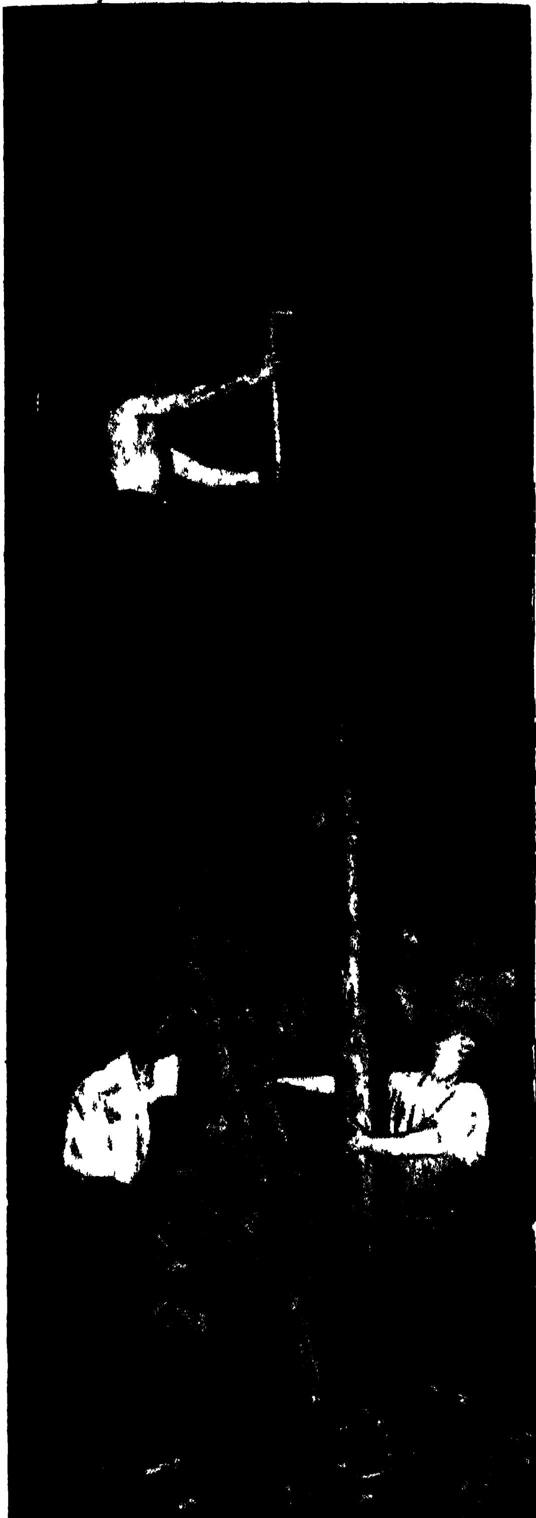


This photograph, taken a thousand feet underground, shows the seam of coal as it runs in the earth's crust. The narrow black layer of carbon was once a luxuriant tropical forest drinking in the warm sunshine and storing it up for man's use millions of years afterwards. But the land sank and the forest was buried in the ocean under mud and clay, which became shale. In the Lancashire coalfields there are eighteen coal seams, and the Saarbrucken coalbeds in North Germany have 224 seams, proving that the earth and the sea in this place must have changed places 224 times !

SEARCHING FOR THE MINER'S DEADLY FOE

These miners are searching for the deadly fire-damp. This gas, which causes so many explosions, is lighter than air, and rises to the roof of the mine. When a safety lamp is held in it, the flame burns blue, and the miner can detect it and take precautions. It escapes from the coal, often with a hissing sound; and in a Wallsend mine one escape of gas gave off 120 cubic feet of gas every minute for years.

PROPPING UP THE EARTH IN A COAL-MINE



The method of getting out the coal varies in different mines and in different districts, as much depends on the character of the seam. But in all cases the roof of the workings must be propped up with iron or timber supports, as the men are seen doing in the left-hand picture. Then they can work, as shown on the right, without fear of being buried under falling coal.

WINNING A NATION'S WEALTH INSIDE THE CRUST OF THE EARTH

The heat is very great in a deep mine, and it increases with the depth, so that the men have to work with very few clothes on. In this picture we see them at work in Yorkshire half a mile below the surface of the ground, and perhaps three or four miles from the shaft. They are literally inside the crust of the earth, and are drilling holes in a bed of basalt to blast it out of the way of the coal.

of bad air impinges on the gauze. Shields are made to ward off the air rush, and other improvements have been made, but to Davy belongs the lasting credit of this great safeguard.

As all the precautions taken did not entirely eliminate explosions, it became clear that there were causes of explosion other than the presence of a considerable volume of gas; and it is now established that a shot which blows back from the drilled hole in the coal-seam in which it has been rammed may ignite certain kinds of coal dust, particularly if small quantities of fire-damp are in the air, and even if the air be free from gases. In consequence, the watering of the main roads of a pit is now one of the recognised methods of contributing to the safety of the miner.

The work of the miner ever has been, and always will be, a warfare with danger. Death lurks at his elbow. He may be poisoned by black-damp (carbonic acid), or white-damp (carbon monoxide), or fire-damp, also called marsh gas (light carburetted hydrogen), or after-damp (the products that creep through a mine after an explosion); he may be crushed by falls of the roof or of coal, for always the weight of the super-incumbent earth is tending to bring down whatever is overhead, and to close up the open roads by pressure on all sides, "creeping" to obliterate the cavities made by man.

The Man who Works Day by Day with Death at His Elbow

Indeed, all his work below is carried on in the midst of forces which, whether he is alert or not, may trap and maim him. In Great Britain about 850,000 men work underground under these conditions, and from 1,000 to 1,300 of them are killed every year, while on an average one in seven suffers annually some recorded injury. In a mining district one out of fifteen of the deaths that occur is a death in the mines, and this in spite of Government inspection for over sixty years, the utmost managerial self-interest, and a widening intelligence and education among the rank and file of miners. Coal has achieved wonders in the world, but it is "won" at a great price in human wreckage.

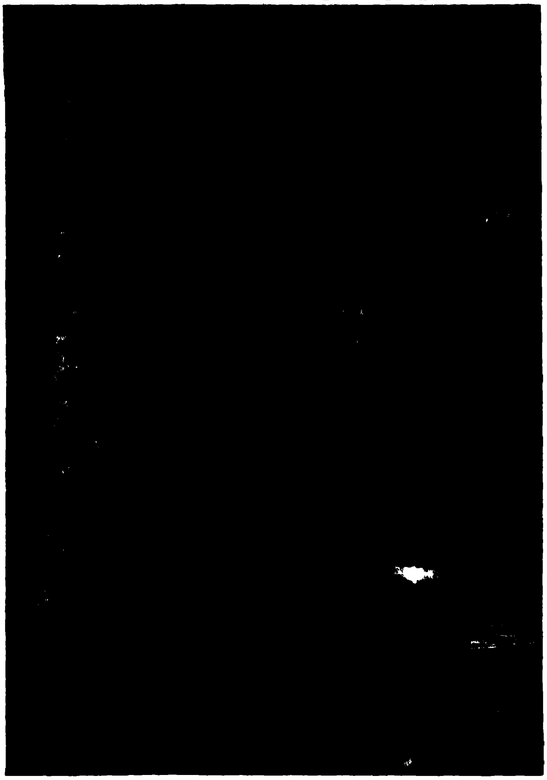
But science is continually working to eliminate the dangers of coal mining by inventing and perfecting new safety devices. Thus, only a short time ago, at the general meeting of the Association of Mining Engineers held at Glasgow, Mr. Ralph, a mining engineer of Newcastle, announced the invention of a fire-damp detector. This is an instrument for detecting the presence of the much-dreaded fire-damp in coal-mines. This gas becomes dangerous when there is about four per cent. of it present in the air. The new invention of Mr. Ralph will enable us to detect the presence of even such small quantities as one-quarter of one per cent. of fire-damp in the air. It may truly be described as epoch-making, for by its means many a dreadful mine catastrophe will be averted, and numerous useful lives saved.

The First Thing to be Done when Coal is Discovered

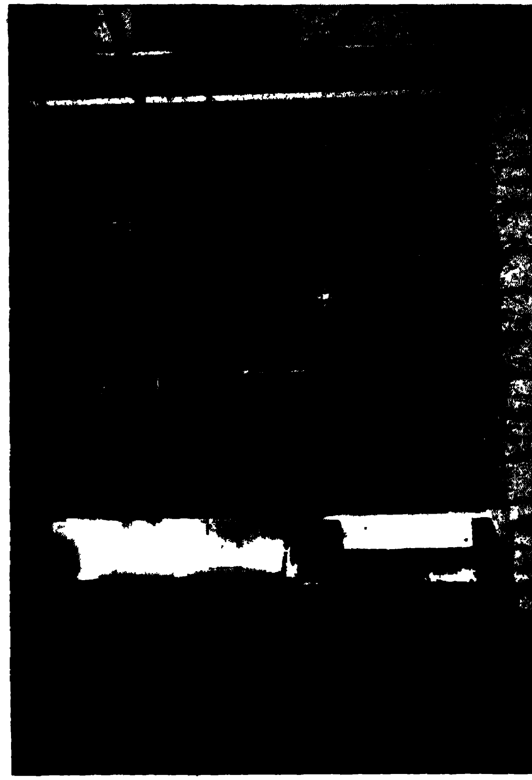
Before a colliery is sunk, experimental boring is started on a site suggested by geological knowledge. Boring to test the earth's strata has been practised in this country since the year 1618. The placing of a shaft is important, and complicated. It should provide, if possible, for at least three conditions—the working of the seam of coal from its lowest point, so that the gradients in the main roads of the mine may fall to the bottom of the shaft and help drainage and haulage; the working of the coal owned from its centre, to prevent unnecessary length of underground ways; and the convenient removal of the produce from the pit-head to the consumer. The shafts sunk are usually circular, as a round shaft best resists pressure; but shafts of various shapes, including square ones, may be found abroad. It is not customary to sink the principal shaft first, but to regard the ventilating shaft as experimental. The cost of sinking depends on the hardness and slope of the strata, and the amount of water, running sand with much water being more difficult than harder layers. The shaft is often lined, or "tubbed," as it descends, with segments of cast-iron rings to keep back the wet, and afterwards is bricked. On reaching the seam to be worked, main roads are driven from the pit bottom, at least two being started at once, and connected as they proceed, to facilitate ventilation. In the neighbourhood of the bottom of the shaft is excavated the stabling for the horses, ventilation being more easy there. The shaft itself is continued below the level of the workings, the covered terminal part, or "sump," being used to receive the drainage of the mine.

Propping up the Earth with Steel in the Underground Roads

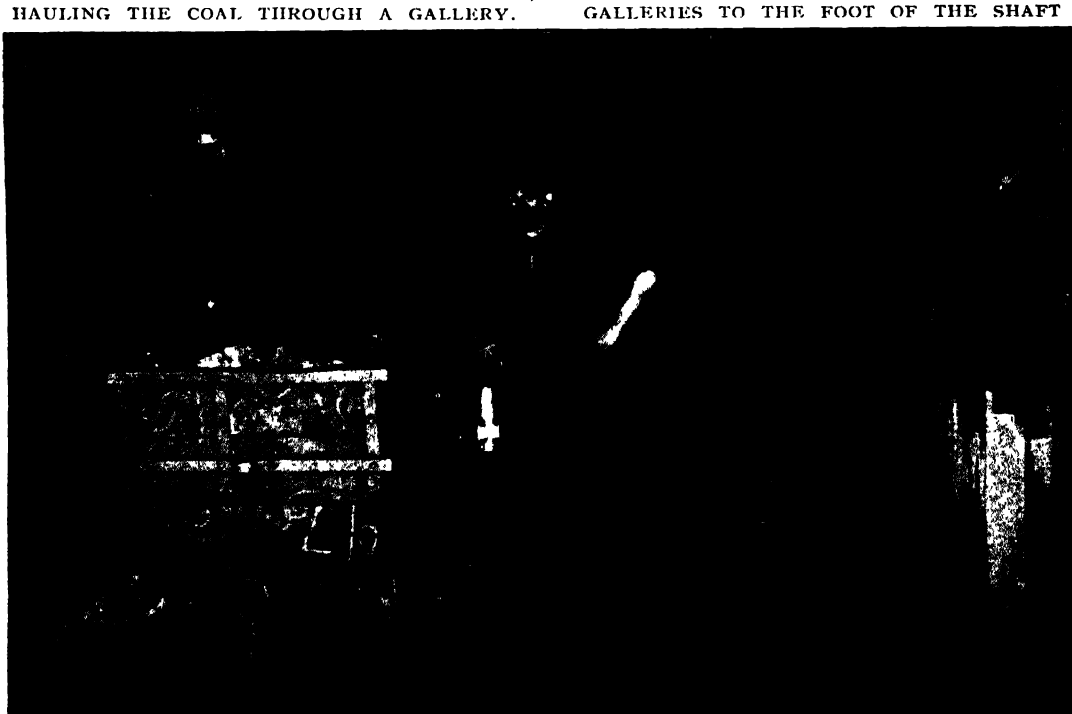
A considerable part of the expense of mining is incurred in timbering the roadways and workings, which are always subject to falls, and are artificially kept open. Steel is now used more and more instead of wood for the support of the roof, especially where pressures are heavy, and the change is an economy, for whereas steel is more than twice as expensive as



A PIT-PONY, LIVING IN PERPETUAL DARKNESS, HAULING THE COAL THROUGH A GALLERY.



TRUCKS HAULED BY MACHINERY FROM THE GALLERIES TO THE FOOT OF THE SHAFT

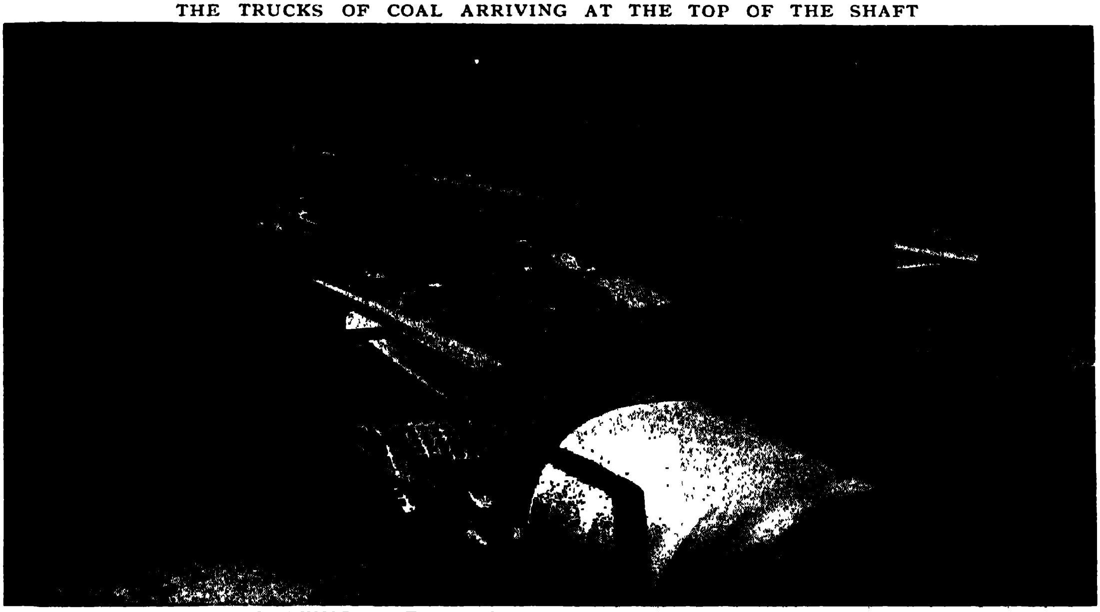


THE COAL AT THE BOTTOM OF THE SHAFT, READY TO BE SENT UP.

The pit-ponies pull the trucks through the galleries to the main workings, where machinery hauls them to the shaft. A cage sometimes takes up twelve trucks at a time. From one to four thousand tons can be brought up a shaft in a day, and it is interesting to reflect that in this way the forest, which grew

A TRAIN BEING LOADED WITH COAL

THE TRUCKS OF COAL ARRIVING AT THE TOP OF THE SHAFT



COAL BEING SIFTED AND SCREENED AT THE PIT-MOUTH

THE COAL BEING TIPPED INTO RAILWAY WAGGONS READY TO BE SENT AWAY

in the sun before the appearance of man, is now brought back to light again by the hands of men. As the trucks come up from the pit they are emptied by a mechanical "tippler," which throws the coal on to screens, where it is sifted into various sizes, and tipped into railway waggons.

wood, its life under the stresses of the mine is six times as great as that of wood.

The pit-frames, or head-stocks, of British collieries, formerly an open structure of wood supporting the pulley-wheel, are now more frequently made of steel. On the Continent the pit-head is often bricked in. The rope almost invariably is of steel wire, in England, and round, and is expected to raise ten times its customary load without breaking. The weight of that load sometimes reaches four tons of coal, besides the added burden of the cage and the rope. Thus, at Cadeby Main, the cage carries at once eight tubs, each with a load of ten cwts., lifting its burden a height of 2289 feet. From the Denaby Main pit in Yorkshire 629,947 tons have been "turned" in a year of 281 working days. The Pendleton colliery in Lancashire is half as deep again as Cadeby Main—namely, 3474 feet—and the Sainte Henriette mine at Flenu, in Belgium, reaches a depth of 3773 feet, a distance considerably greater than the height of Snowdon—so marvellously has the reach of the coal mine extended and the swiftness of coal-raising increased.

The Various Ways in which the Coal is Got Out of its Solid Bed

Haulage in the pits is now generally by mechanical means along the main roads, and by horses or ponies between the workings and the main roads.

Electricity is often employed for lighting purposes near the bottom of the shaft, but not near the workings, as they are constantly being moved back as the coal is taken out.

The systems of getting the coal from its solid bed differs in various localities and countries. Near the bottom of the shaft much of it is left to prevent subsidence. The two most general methods are by board and pillar working, removing the coal in rectangular blocks, and by long-wall working in which the whole face of the seam is attacked and removed. As the coal is removed, the roof being propped up in the workings, the refuse is thrown back, or is built up, according to its character, behind the workers, into the waste open space, "goaf" or "gob," where the coal seam was, and the remaining space gradually closes in owing to the earth's superincumbent and surrounding pressures after the timbers are removed, and the working stalls along the face of the seam have been further advanced.

The actual quarrying of the coal is managed in various ways, sometimes by coal-cutting machines, but the most general method is by "holing" underneath the seam in the underlying stratum, if it is sufficiently soft, or, if not, in the coal itself. While doing the work the miner lies on his side, wielding a pick till the length of the face allotted to him is undercut as far as he can reach. Holes for shots are then drilled in the coal face above the undercut part, and charged with an explosive, and the firing brings down the wall of coal as far back as the holing has allowed. The mineral is then broken up so as to allow of it being handled, and is loaded into small waggons, which are brought to the workings along miniature railways that are extended as fast as the coal-seam is removed.

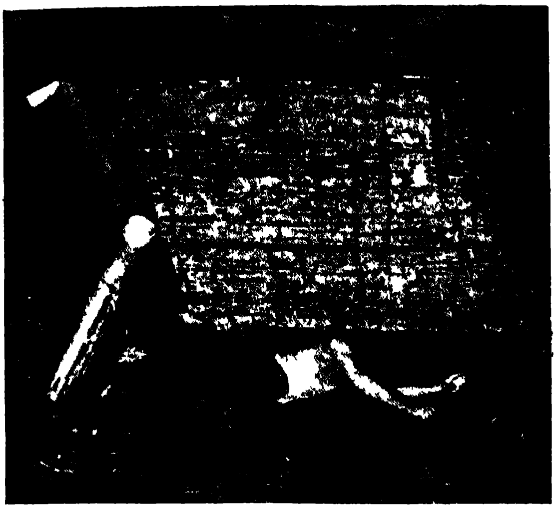
The Work of the Coal when it Leaves its Age-long Resting Place

Many of the uses of the coal that is so hardly won from its deeply hidden, age-long resting place are obvious to the least observant. We all see its familiar consumption for domestic warming and cooking, and its power-producing feats, when transformed into heat in working every type of machinery, the swift and ponderous express engines, the great marine monsters singing their rhythmical hymn, the myriad machines of our factories and workshops. We know that from it has been produced the gas for our lighting and for running machinery in smaller applications than the steam-worked wonders. We know that it has smelted the metals which provide material for nine-tenths of the mechanical contrivances of mankind. We recognise that coal, in alliance with iron and its compounds, has made modern industrialism possible. But there are other uses to which coal has been put in recent years that are less obvious and perhaps equally interesting, if not so essential. The chemical products of coal are one of the marvels of our generation.

From a ton of Newcastle coal may be produced 10,000 cubic feet of gas, 140lb. of tar, about 1500lb. of coke, and 20 to 25 gallons of watery liquid. The use of the gas and the coke is familiar enough; it is the tar and watery liquid that furnish an opportunity for modern magic.

The Marvels that a Touch of the Scientist's Wand Brings from a Piece of Coal

From these waste products, as they used to be called, can now be extracted colouring matters to please our æsthetic tastes, medicines for our ailments, perfumes for our olfactory pleasure, flavourings to suit our palates, burning oils for our domestic convenience, lubricating oils for our machines, paraffin wax for our candles,

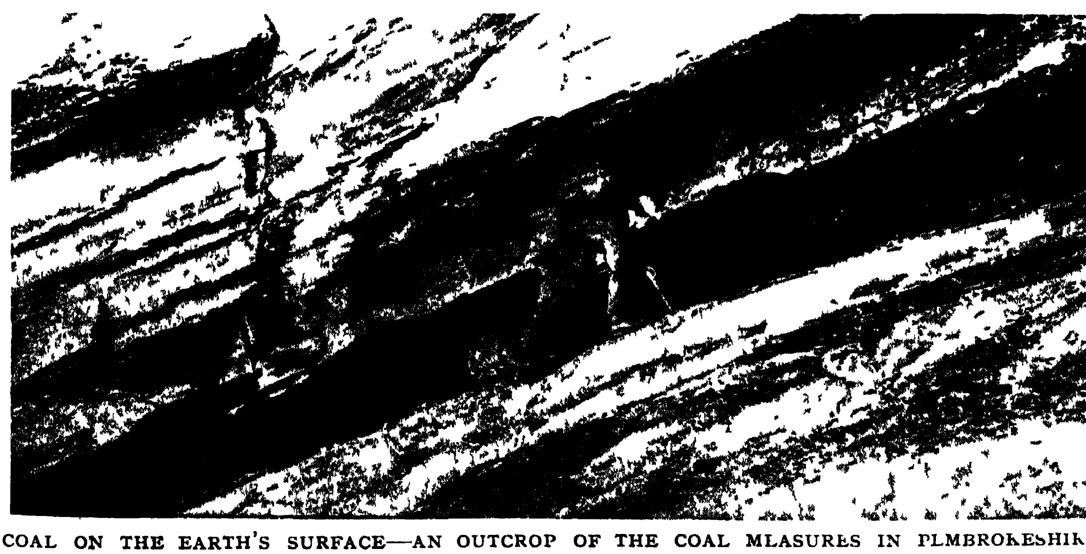



THE HUMAN MOLES—LIFE HALF-A MILE BELOW

These pictures show how the miners cut away the lower part of the seam of coal and lie underneath the mass which must be supported by beams placed slantwise so that if the coal begins to drop it will not drive away the supports. The position of the men is extremely perilous and many are killed by falling coal. When the foundations are dug out, the great mass falls or is knocked down by wedges driven in at the top

ammonia for cleansing and manures, acids of various kinds and ingredients used in the manufacture of paper and soap and glass. From a ton of coal can be extracted 30lb of crude sulphates saleable at £12 a ton. It will give up that which will dissolve indiarubber and creosote to pickle timber. From it we get lampblack, varnish, naphtha, benzene and aniline dyes of forty shades, insecticide for crops, carbolic acid for surgery, salicylic acid for the preservation of food, asphalte to pave our streets and—in competition with itself—briquettes or patent fuels. To pharmacy it has given the modern medicines of sleep and the saccharine that displaces sugar, and it provides some of the most essential materials for the student in microscopy through its colouring matters and for the photographer engaged in his development processes.

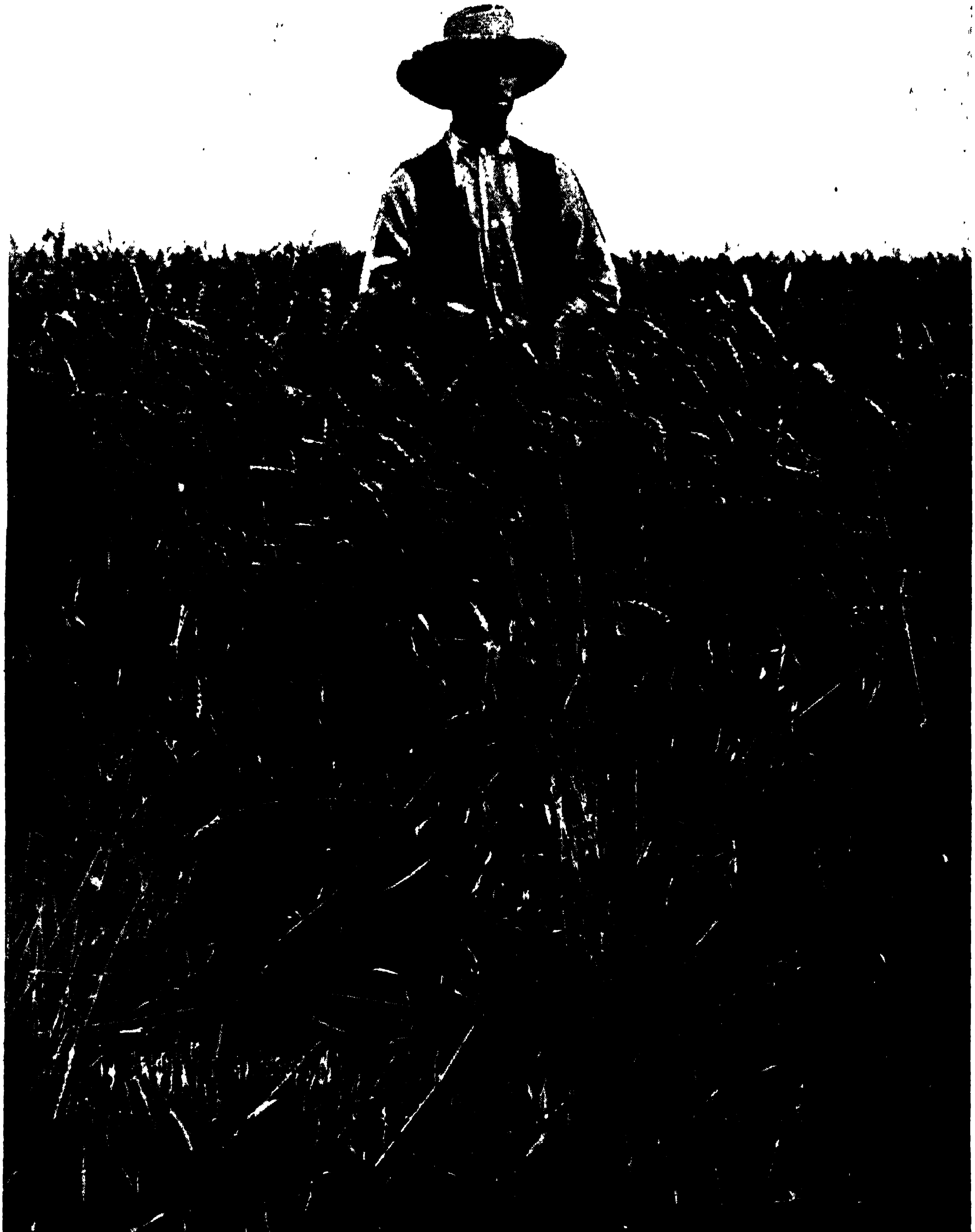
Whatever may be the future of coal in this country or elsewhere no one can deny that its story during the last century, though darkened so often by disaster and death, has been illuminated by steady triumphs and made brilliant by scientific surprises. What may not be in store for man when such wonders can be evoked from this unpromising sample of decaying rock!



COAL ON THE EARTH'S SURFACE—AN OUTCROP OF THE COAL MEASURES IN PEMBROKESHIRE

Some of the photographs in these pages are taken at the Silverwood Colliery, Rotherham, Sheffield. Others are by Mr H W Hughes, Mr H A Chapman, and Mr W E Garforth, President of the Royal Institute of Mining Engineers

A GLIMPSE OF A WHEATFIELD IN CANADA



It is in such glorious fields as this that the enormous wheat crop of the British Empire is grown. The wheatfields of the empire produced in 1909 nearly 1700 million bushels, an increase of 146 millions in a single year, the increase itself being more than double the entire wheat production of the United Kingdom.

The wheatfield shown here is on one of the immense farms along the Canadian Pacific Railway.

EMPIRE AND MOTHERLAND

A Commercial Survey of the Vast Potentialities of the Britains Beyond the Seas

THE BRITISH EMPIRE'S NATURAL WEALTH

LET us pass from our survey of the economic position and resources of Britain herself to the consideration of the magnificent territories for which Sir Charles Dilke coined the title "Greater Britain." We have seen how limited in many important respects is the natural wealth of the 120,000 square miles whereon the greater part of the British race lives and works; we shall see how enormous and how varied are the productions of the Britains beyond the seas, which, although they contain but about one-fifth of the British race, cover an area nearly a hundred times as great as that of the British Isles.

The far-flung congeries of States, partly a federation of free and self-governing peoples, and partly a dominion of controlled and guided nations, or colonies, covers one-fifth of the world's land area, and includes in its governance one-fourth of the world's inhabitants. With no possibility of war between one-fourth of mankind, with constant and increasing opportunity for intercourse, for mutual understanding, and for Imperial conference, it should be possible in future to do much by way of synthesis for a large part of the world.

The test by metals which we applied in examining the economic position of the United Kingdom gives us an even more significant result when applied to Greater Britain.

METAL OUTPUTS OF GREAT BRITAIN, THE EMPIRE, AND THE WORLD.
Metals of native ores only, in 1909. Gold and silver are given in kilos; the rest in metric tons.

Metal	Great Britain	Greater Britain	All the World
Iron	4,900,000	700,000	60,000,000
Copper	500	72,500	893,000
Zinc	4,000	151,000	856,000
Lead	23,000	204,000	1,050,000
Tin	5,300	59,700	117,000
Gold	30	395,000	686,000
Silver	4,400	1,365,600	6,340,000

When dealing with the resources of Britain it was not worth while to refer to the quite insignificant production of a few pounds' worth of gold in Wales, and of a few thousand pounds' worth of silver in connection with our lead mines. When we deal with Greater Britain, however, gold and silver bulk largely in the figures. We see that in 1909 Greater Britain produced more than half the world's gold, and about one-fifth of all the world's silver.

With regard to copper, zinc, lead, and tin—after iron the most useful metals to man—the position is almost as striking as in regard to the precious metals. Of tin more than one-half, and of lead about one-fifth, of the world's total supply is the output of Greater Britain, and of zinc the British Empire's share is about one-sixth. In copper Greater Britain is not so fortunate. Nevertheless, one-twelfth of the world's copper is produced in our over-sea Empire.

It will be obvious from the consideration of these economic facts that the British Empire covers not merely a large part of the world's area, but that the British one-fifth of the world must include no little of the world's most profitable mines.

But iron is more valuable to man than all the other metals put together; and particular attention should be paid to the fact that while in 1909 the world as a whole produced about 60,000,000 tons of iron, and while the United Kingdom produced nearly 5,000,000 tons of iron from her own ores, the whole of the British Empire, outside the United Kingdom, produced iron ore with a metallic content of only 700,000 tons.

The explanation of these figures should be thoroughly understood. There is a great deal of iron ore in the British Empire, but it is not always worth while to mine

it because of the serious freight factor, and because *Greater Britain is not yet developed as a great power area.*

Coal, we have seen, is at present the chief arbiter of the distribution of industry. Small as the United Kingdom is, insignificant as is its area compared with that of Greater Britain, the Mother Country far out-rivals her daughter nations and the British Empire at large in coal output. Indeed, at present Greater Britain is a poor producer of coal, as the table at foot of page shows.

The whole of Greater Britain produces but about 40,000,000 tons of coal in a year, or between one-sixth and one-seventh the output of the Mother Country. Nevertheless, the oversea output has much increased of late, and is four times as great as it was twenty years ago.

It is, then, of the deepest interest and importance to inquire as to the character of the colonial coal resources. Unfortunately, in this, as in many other matters, the world has not the full information it ought to have at the beginning of the twentieth century, which it certainly will have when the importance of scientific conservation is widely understood. A certain amount of detail was collected for the last Royal Commission on Coal Supplies, and this goes to show that we may expect a large development of coal production in the British Empire.

India, which, it will be seen, produces yearly about 13,000,000 tons of coal, is certainly rich in fuel, although not so well favoured as that dark horse of industry the Chinese Empire. There are perhaps 35,000 square miles of coal area in India, but this is a very rough estimate, and there is little information of any value as to the content of the coal areas. The balance of evidence goes to show that India has large but not comparatively great coal potentialities. Moreover, Indian coal is not of a very high quality, being 30 to 40 per cent. inferior to Welsh coal in heating power.

We turn to Australasia, where coal production has trebled in the last twenty years, but is still only about 12,000,000 tons a year. The New South Wales coal measures have been estimated to contain over fourteen thousand million tons of coal. At Newcastle, New South Wales, coal has been mined for a century, but only about a hundred million tons have been raised in that period. Victoria has very large deposits of brown coal, or lignite, but little is worked at present. Queensland, Tasmania, and Western Australia also possess coal deposits. A former Government geologist of Queensland, Mr. Jack, has given it as his opinion that the coalfields of that State are "practically unlimited." With regard to New Zealand, it has been estimated that the dominion has about 1200 million tons of available coal. In one sense this is a great deal, but it is less than five times as much as the United Kingdom produces in a year!

Altogether, it may be doubted whether the great area of Australasia can be considered likely to become, in the comparative sense, a great coal area, and this view is borne out by the length of time during which some of the chief measures have been worked.

The fine Dominion of Canada next engages our attention. Here the coal area is literally enormous, extending to nearly 100,000 square miles. Next to China and the United States, Canada has the greatest coal area of any country. Coal area, however, is by no means the same thing as coal content, or, what is more important, coal commercially available. The chief developments have taken place in Nova Scotia and British Columbia. A rough measure of *availability* is given by the respective coal developments of Canada and the United States. Each has been colonised and developed for approximately equal periods, and yet to-day, while Canada produces but about ten million tons of coal a year, the

THE COAL OUTPUT OF THE BRITISH EMPIRE IN THREE DECADES

TERRITORY	Tons in 1890	Tons in 1900	Tons in 1909
UNITED KINGDOM	181,600,000	225,200,000	263,800,000
GREATER BRITAIN			
India	2,200,000	6,100,000	13,000,000
Australia	3,500,000	6,400,000	10,200,000
New Zealand	600,000	1,100,000	1,900,000
Canada	2,700,000	5,200,000	9,300,000
Cape Colony	30,000	200,000	100,000
Transvaal	—	400,000	2,700,000
Orange Free State	—	—	400,000
Natal	80,000	200,000	1,800,000

United States of America produces four hundred million tons, or forty times as much. As there is no reason to suppose that less intelligence has been applied to Canadian than to United States coal resources, we must take it that, however great the coal area of Canada may be, her commercially useful coal is not nearly as great as that of either the United Kingdom or the United States. In this lies the explanation of the remarkable contrast between the populations of Canada and her southern neighbour, Canada having a population of about 7,000,000, and the States of about 95,000,000 people, advancing in population at the rate of about 2,000,000 a year. Coal, as we have said, is a magnet for population.

It remains to consider South Africa. As a whole, the African Continent is exceedingly poor in coal measures, but South Africa has the best on the Dark Continent. As will be gathered from the table, Cape Colony, the Transvaal, and the Orange Free State are all small coal producers, and there is also coal on the Zambesi, but the production of all the South African fields put together is barely as great as the increase of production by the United Kingdom in a year. There does not seem any reason to believe that the South African fields, though valuable, will ever become great.

The Comparative Poverty of Greater Britain in Coal and Her Richness in Water Power

Thus, amidst a great deal of uncertainty one thing is certain, and it is that after many years of exploration and development Greater Britain is still, as a whole, a comparatively poor producer of coal. That is, when comparison is made with the really great coal-producing countries of the world —Britain, the United States, and Germany. Apart from these three great leaders, however, British Empire coal ranks for much of the coal of the rest of the world.

As far as water-power is concerned, Greater Britain is, of course, far better furnished that the Mother Country. In Canada, New Zealand, and South Africa we have conspicuous examples of the harnessing of natural supplies of water-power and their utilisation for industrial purposes. The Victoria Falls, on the Zambesi, which are 400 feet high and some 5000 feet wide, will doubtless some day be the centre of a great industrial field, and the magnificent power which they furnish will be carried by mains to great distances, to feed mines and factories and towns.

In New Zealand the Government is wisely developing water-power on a national scale. New Zealand is a mountainous country, exceptionally rich in water-power resources. A well-known American engineer, Mr. L. M. Hancock, was employed to investigate the subject; and the result of his inquiry was so favourable that £500,000 was voted in 1911 for State electric-power works based on water-power.

A Development which would Pour Millions of People into New Zealand

Mr. Hancock reports that with the cheap power thus furnished New Zealand can accomplish wonders. He estimates that every city, town, and hamlet in the dominion can be furnished in this way with power, light, and heat for railways, factories, warehouses, and homes. There is enough water-power in New Zealand to do the manufacturing of all Australasia and a great part of the Orient. New Zealand is advantageously situated for trade in the Pacific, and it is so near to great markets that when the dominion has properly developed her magnificent "white coal," her possibilities, as Mr. Hancock puts it, "are almost beyond the bounds of fancy."

Such a development, which is certain rather than probable, would certainly change many currents of existing trade. New Zealand, instead of exporting wool to be manufactured in Europe, would herself multiply her present population of about one million into tens of millions, and create upon the basis of her water-power and her fine supplies of material a great industrial output, with an export trade in the Pacific and through the Panama Canal to places even farther afield.

Seven Hundred Million Bushels of Wheat from British Fields

Let us now consider Greater Britain as a food producer. It is common knowledge that our daily bread is for the most part brought by commerce from over the sea. The British wheat crop varies from fifty to sixty million bushels a year, whereas we consume about five times that quantity. It is far otherwise in the Britains beyond the seas. The British Empire as a whole produced in 1909 nearly seven hundred million bushels of wheat, and the United Kingdom wheat crop is comparatively so insignificant that it amounts to far less than the increase of the Empire crop in a single year. In 1909 the total Imperial wheat crop *rose* by 146,000,000 bushels, while the United Kingdom crop *amounted to* 63,000,000 bushels. As recently as 1895 the British Empire grew about three hundred million bushels, so that in half a generation the crop has

VARIED SCENES AND WORKERS IN THE

SINKING A PIT FOR TIN IN NIGERIA

SUGAR-CANE PICKERS IN JAMAICA

The development of the vast commerce of the British Empire, the far-flung congeries of state which cover an area nearly a hundred times as big as the British Isles, is one of the most astonishing features

BUILDING UP OF THE EMPIRE'S WEALTH

WEEDING THE YOUNG PLANTS IN A RUBBER PLANTATION IN MALAY

PICKERS AT WORK IN ONE OF THE VAST TEA PLANTATIONS IN CEYLON

of modern world-development. One-fifth of the earth is in the hands of the British race, and these pictures bring before us some of the varied scenes in which the natural wealth of the Empire is developed

more than doubled itself, which is a further illustration of that extraordinary rapidity of world development which we have already considered.

The United Kingdom production of barley, so largely cultivated for malting, forms a very large proportion of the total Imperial output, but with regard to oats the figures are almost as striking as for wheat, the British home crop being about 180,000,000 bushels out of a total Empire crop of nearly 550,000,000 bushels.

The production and consumption of the cereals in the British Empire are set out clearly in the table at the foot of this page.

We see Great Britain producing ten times as much wheat as the United Kingdom, and producing for export an amount almost equal to the home country's requirements. We see barley little used in the Empire outside the Mother Country, almost the entire Greater Britain crop being a surplus for export. We see the Greater Britain crop of oats so great as to be six times greater than the home country's excess of consumption. The Greater Britain crop of maize is largely needed where it is grown; but, even so, more than half of the Imperial crop is available for export.

In view of these important figures, it is not surprising that the United Kingdom's imports of the cereals are being more and more largely drawn from Greater Britain.

Passing to other foodstuffs, the horned cattle of Greater Britain are eleven times as great as those of the home country, which have advanced little in recent years. The sheep of Greater Britain number about 180,000,000, against 32,000,000 in the United Kingdom. At the present time, probably about one-half of the United Kingdom's home consumption of meat is home-grown, but the proportion of home-meat is likely to decrease in the future, and an increasing amount is likely to be drawn from Imperial and other sources. With regard to tea, coffee, cocoa, and sugar, the United Kingdom has no home supply, and the enormous production of tea in India and Ceylon enables us to draw the greater part of our supplies from Greater Britain.

Turning to the raw materials of the textile trades, the production of cotton within the British Empire has increased by about 70 per cent. in the last half generation, but Imperial cotton still forms a very small fraction of the world's supply, and the United States still furnishes the greater part of the requirements of British and foreign cotton mills. The American monopoly of the raw cotton supply is a really remarkable thing, and there does not seem any good reason to suppose that the world need be for ever dependent upon it. In Africa, Australia, the West Indies, South America, and India it should be possible so to multiply the world's cotton crops as to reduce very greatly the price of the material and to give a fresh spur to the world's cotton producers. The constant harassing and check of British and foreign mills by the periodical shortage of what is to all intents and purposes a single source of supply is fraught with the gravest danger to hundreds of thousands of the world's industrial workers.

With regard to wool, the British Empire has in Australasia one of the chief world supplies. In the last fifteen years the Empire's output of wool has increased by about 40 per cent., and yet has failed to keep pace with the world's increasing demand for wool caused by the rising standard of life in the North Temperate Zone, where wool is such a common necessity of existence. In the same period the United Kingdom wool crop has been almost stationary.

In India the British Empire possesses the world's greatest source of jute, and the

THE BRITISH EMPIRE'S CEREALS—PRODUCTION AND CONSUMPTION FOR 1909

CEREALS	PRODUCTION	CONSUMPTION	TOTALS COMPARED
	Bushels	Bushels	Consumption more than production
UNITED KINGDOM			
Wheat	63,000,000	270,000,000	+ 207,000,000
Barley	69,000,000	112,000,000	+ 43,000,000
Oats	179,000,000	230,000,000	+ 51,000,000
Maize	nil	78,000,000	+ 78,000,000
GREATER BRITAIN			Less than production
Wheat	627,000,000	361,000,000	− 266,000,000
Barley	57,000,000	5,000,000	− 52,000,000
Oats	366,000,000	35,000,000	− 331,000,000
Maize	53,000,000	22,000,000	− 31,000,000

THE BRITISH EMPIRE'S GROWTH IN MATERIAL WEALTH

COMMODITIES PRODUCED IN EMPIRE AND MOTHER LAND		PRODUCTION IN 1895	PRODUCTION IN 1909	Increase per cent. Decrease shown by –
Coal	United Kingdom	189,700,000 tons	263,800,000 tons	39·0
	British Empire	201,600,000 tons	303,200,000 tons	50·0
Copper	United Kingdom	£27,000	£19,000	– 29·6
	British Empire	£800,000	£4,300,000	437·5
Tin	United Kingdom	£447,000	£696,000	55·7
	British Empire	£4,000,000	£8,300,000	107·5
Iron Ore	United Kingdom	12,600,000 tons	15 000,000 tons	19·0
	British Empire	12,800,000 tons	16,300,000 tons	27·3
Pig Iron	United Kingdom	7,700,000 tons	9,500,000 tons	23·3
	British Empire	7,740,000 tons	10,200,000 tons	31·8
Gold	United Kingdom	£18,000	£4,000	– 77·7
	British Empire	£10,900,000	£54,000,000	395·4
Silver	United Kingdom	*£35,000	£14,000	– 60 0
	British Empire	£600,000	£3,800,000	533·3
Diamonds	United Kingdom	—	—	—
	British Empire	£4,800,000	£6,400,000	33·3
Wheat	United Kingdom	*38,000,000 bushels	63,000,000 bushels	65·7
	British Empire	318,000,000 bushels	690,000,000 bushels	116·9
Barley	United Kingdom	75,000,000 bushels	69,000,000 bushels	– 10 6
	British Empire	97,000,000 bushels	126,000,000 bushels	29·9
Oats	United Kingdom	174,000,000 bushels	179,000,000 bushels	2·2
	British Empire	300,000,000 bushels	545,000,000 bushels	81·6
Maize	United Kingdom	—	—	—
	British Empire	39,000,000 bushels	53,000,000 bushels	35·9
Cattle	United Kingdom	10,700,000 head	11,800,000 head	10·3
	British Empire	107,000,000 head	130,000,000 head	21·5
Sheep	United Kingdom	29,800,000 head	31,800,000 head	6·7
	British Empire	164,000,000 head	213,000,000 head	29·8
Tea	United Kingdom	—	—	—
	British Empire	242,000,000 lb	458,000,000 lb	89·2
Coffee	United Kingdom	—	—	—
	British Empire	58,000,000 lb	39,000,000 lb	– 32·8
Cocoa	United Kingdom	—	—	—
	British Empire	40,000,000 lb	133,000,000 lb	232·5
Sugar	United Kingdom	—	—	—
	British Empire	50,000,000 cwts.	57,000,000 cwts.	14·0
Cotton	United Kingdom	—	—	—
	British Empire	1,070,000,000 lb	1,817,000,000 lb	69·8
Wool	United Kingdom	135,000,000 lb	142,000,000 lb	5·2
	British Empire	928,000,000 lb	1,288,000,000 lb	38·8
Jute	United Kingdom	—	—	—
	British Empire	20,000,000 cwts.	26,000,000 cwts.	30·0
Rubber	United Kingdom	—	—	—
	British Empire	12,200,000 lb	15,000,000 lb	22·9

* A bad year ; the crop in 1894 was 61,000,000 bushels

Indian crop output of this material has increased by almost a third in the last fifteen years.

With regard to hides and skins, the output of the British Empire may be gauged by the animals which it possesses; and since 1895 the cattle of the British Empire have increased by one-fifth and her sheep have increased by one-third.

It is unfortunately impossible to give definite statistics with regard to timber, but it may be said that Greater Britain is almost as rich in timber of various sorts as the United Kingdom is poor.

Finally, it may be mentioned that the British Empire contains the greatest diamond mines of the world, the output being now worth over six millions sterling per annum, an increase of about one-third in the last fifteen years.

The story of the wonderful development of the material wealth of the British Empire is told in the important table on page 491, which gives the output of twenty-two of the chief commodities in 1895 and in 1909.

The Unique Resources of the Oversea Dominions and their Rapid Advance

In this table are given a series of notable contrasts between the productive capacity of the Motherland and the territories beyond the seas, and they show how enormously greater is the development of the British Empire than that of the Mother Country. It helps us to realise, if only dimly, the magnificent and in some respects unique resources of the oversea Britains, and the extraordinary rapidity with which they have advanced in our own time. So far the development has been chiefly in the production of foods and of materials. It will be observed that the iron figures have not advanced with the tremendous strides of those relating to corn. Nevertheless, our study of the power resources of the Empire makes it plain that many parts of the oversea dominions may reasonably hope to become, through the possession of coal or of water-power, producers of manufactured articles on a considerable scale.

Such is the inheritance of the modern Briton. The far-flung Dominions which own British sovereignty are rich in native fertility, in metals, and in the supplies of energy which man has learned to harness. Here, at the Atlantic gateway of Europe, the Mother Country still wields commercial supremacy, and bases upon one of the three or four of the greatest power supplies of the world a gigantic and varied industrial output, utilising all the world's harvests and mines and forests. Across the Atlantic the great Dominion of Canada is rapidly spreading civilisation from east to west of the North American Continent, and assuredly building up what will become one of the greatest nations of the world. The produce of her fields and forests, fisheries and mines, is at present so much greater than the needs of her seven million people that she goes to market with corn and meat, butter and cheese, fish and fruit, timber and hides, in enormous quantities.

The Boundless Possibilities of India, South Africa, and Australasia

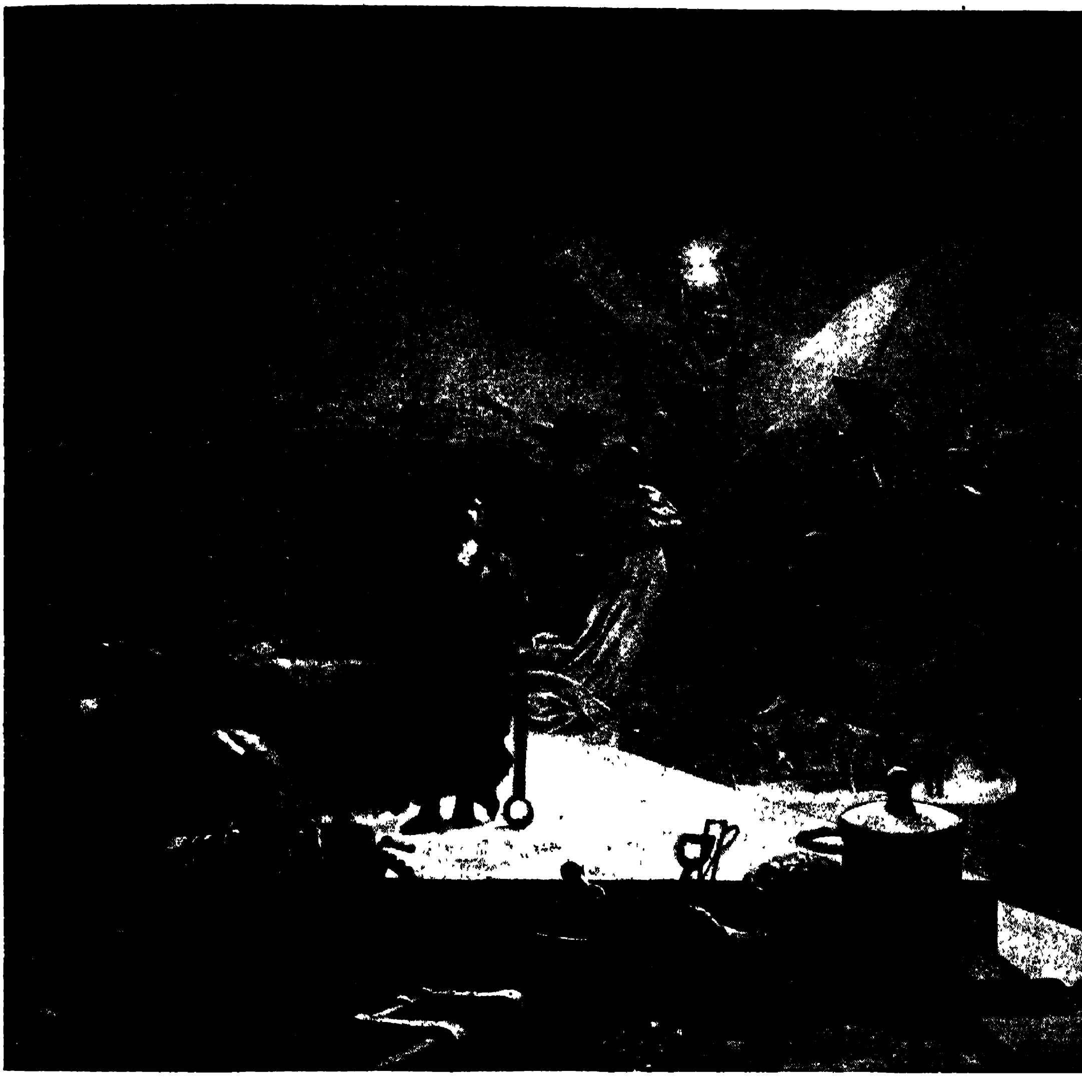
Eastwards we see the many peoples of India still for the most part engaged in agricultural pursuits, and still for the most part exceedingly poor, but yet possessing boundless possibilities of development. We see her exporting corn and cotton and silk, jute, hemp, and hides, tea, and spices and dyes, to pay her way, and to draw in exchange the manufactures of Great Britain.

Away South, the newly made Union of South Africa, with its small white and great coloured population, has as yet given us but a hint of the economic developments which are doubtless before her. At present she contributes to the export market chiefly gold, diamonds, copper, and wool. It is not upon the precious metals, however, that industry and commerce are built on a great scale. Coal is immeasurably superior to gold, and iron to diamonds, in the making of nations, and the well-wishers of South Africa must hope for the development of her power supplies.

Far away in the Pacific the Southern Cross gleams upon the Commonwealth of Australia and the Dominion of New Zealand. We have seen how rich are these lands in coal, or in water-power, as well as in fertility. Great and varied already are the exports of Australia. She sells corn and meat—of beef almost as much as of mutton—dairy produce and fruit, hides and skins, oil and tallow, copper and lead, tin and zinc, gold and silver, wool and leather.

The Prospect of Enormous Development Under a Common Flag

The Dominion of New Zealand, although consisting of only about 200,000 families, already takes an important part in the world's commerce. She goes to market with corn and meat, hides and skins, timber and wool, in considerable quantities. We have already seen that the day may come when the beautiful islands of New Zealand, favoured with one of the best climates in



THE BUILDERS UP OF THE WORLD'S WEALTH—FROM THE PICTURE BY THE FRENCH ARTIST PAUL SINIBALDI

the world, may do a thriving export trade of a very different character.

Not until recent years has there been any considerable measure of realisation of the mighty potentialities of the British Dominions, and even now it may well be doubted whether any considerable proportion of the hundreds of millions of people who populate them have any proper conception of what it is practicable to do by way of making the wealth of the Empire of the highest possible use and value to those who have the good fortune to inherit it. The possession of a common flag, and the possibility of approaching questions of commercial development without extremes of national prejudice, should make it not impossible, before many years have passed, to co-ordinate Imperial productive powers, to cultivate and render fruitful vast areas which are now economically barren, to redistribute populations for their own and the world's great advantage, and to set the wheels of commerce running with a tithe of the friction which now obtains.

Given an Empire of enormous area, of varied climate, and of splendid resources, the duty lies before all the British peoples of conserving its natural advantages, and of building not merely for the present but for posterity. It is a happy thing that at the beginning of the twentieth century there are not wanting signs that those entrusted with the governance of these vast Dominions are rising to the height of the unparalleled opportunity which is theirs.

THE TERROR OF FAMINE IN INDIA—FAMISHING PEASANTS APPEALING FOR RELIEF

Famine seems to be a determining factor in the relative proportion of sexes, for during such periods more boys are born than girls. According to some authorities an abundance of food, especially in the female parent, is conclusive to the birth of a girl, while scanty nutrition would result in the birth of a boy.

THE MINORITY OF MEN

An Extraordinary Problem in Men and Women—The Disturbance of the Natural Balance Between the Sexes

IS IT POSSIBLE TO DETERMINE SEX?

It is doubtful if anything has so important a bearing on the general position of human affairs as the proportion of the numbers of the sexes. At the present time there are in Great Britain considerably more than one million more females than males, and some men of science are inclined to think that out of this fact arise many of the chief problems of our society. The extraordinary feature in this inequality between the number of the sexes is that it occurs among a nation in which the male population is not kept down by warfare. It seems to show that the thinkers of the older school were somewhat incorrect in holding that war was the chief factor in disturbing the balance of the sexes; and younger men of science are now casting about for some new theory which will cover and explain all the elements of the problem.

The trouble is that our sources of information are at present limited. Only in highly civilised societies is the numbering of the people conducted in such a manner as to show clearly the relative numbers of the sexes at various ages. We are reduced to conjecture in regard to the Chinese race, for example. We know that among the negroes of America the preponderance of male over female births is either very small or non-existent. These negroes, however, live in peace and comparative plenty, and it would not be safe to presume that all the races of African negroes exhibit the same balance between the numbers of men and women.

We are thus confined, in our search after fairly exact and detailed information, to the statistics of the European races. The figures for the whole of Europe show that for every hundred female children born, there are one hundred and six males. But if a more limited range or a shorter period is taken, some deviations from this proportion are found. For instance, the following ratio of the sexes to each other between the years 1887–95 is given by Luigi Bodio. The figures show the relation at birth.

Number of Males for Every 100 Females

Country	Males
England	103·6
Belgium	104·5
Switzerland	104·5
France	104·6
Hungary	105·0
Germany	105·2
Russia	105·4
Holland	105·5
Austria	105·8
Italy	105·8
Spain	108·3

These figures give the number of births, and they go to show that, in spite of the varying conditions, social and political, obtaining in the different countries, the proportion in the number of male and female infants born remains nearly the same. This proportion, however, differs considerably from that of grown-up men and women. In Europe at the present time there are about 1024 women to every 1000 men. The excess of males at birth is more than made up by the greater mortality of boys as compared with that of girls. At about the twelfth to the fifteenth years the numbers become equal. After the thirty-fifth year the men die at a higher rate than the women, and this finally brings about a preponderance of females.

It is remarkable, however, that in the East of Europe and in the Balkan Peninsula there is a striking exception to the general rule; for in these regions there are more men than women. This seems to throw some light on the problem. In these parts of the world women work almost as hard as men; they are equally exposed to the dangers of disease and the hardships of life,

and they therefore succumb in about the same number, and the original proportion of the sexes is thus maintained. On the other hand, this fact does not serve fully to explain the heavier mortality among male children which generally obtains throughout Europe. Up to the age of thirteen, boys and girls as a rule lead similarly sheltered lives. It is extravagant to suppose that boys receive from their mothers less care than girls, and the fact that fewer of them survive must be attributed to the more resistant powers of the female constitution.

Why the Burden of Making Progress Falls Chiefly Upon Man

No doubt men have more active strength than women. It has been calculated that the civilised woman is little more than half as powerful as the civilised man. Perhaps a considerable part of the difference in the bodily powers of the sexes can be attributed to persistent difference in training, but it is nevertheless clear that man has naturally more power than woman. Woman's blood is thinner and more watery than that of man. A man possesses on the average 5·2 million red corpuscles per cubic millimetre in his blood, while a woman has only 4·9 million corpuscles. There is no more conclusive evidence of an organic difference between man and woman than these tests of the blood. They show that man is better fitted for an active and strenuous life, and they afford an explanation for the curious fact that he is the instrument of progress. Man, as a rule, produces the variations in bodily structure and mental equipment on which the evolution of the race depends. On him falls the burden of striking out new paths. He is more unstable; he goes farther backward and farther forward. Both idiocy and genius are commoner among men.

The Woman who Stores Up Energy and the Man who Lives on His Capital

Men, in short, represent the progressive element in human life, and women the conservative element. A grand difference in plant and animal life lies in the fact that the plant is concerned chiefly with storing energy, while the animal is occupied mainly in consuming it. The plant, by a very slow process, converts lifeless matter into vital substance, spending little energy and living at a profit. The animal is unable to change lifeless matter into vital substance, but it has developed powers of activity which enable it to prey on plants and other live things; and, in contrast with plant life, it lives at a loss of energy. Some men of science regard woman as the more plant-like and man as the more animal-like form of humanity. Woman has to store up energy for her function as a mother, while man lives, so to speak, on his capital. Man is by nature more active, more adventurous, more spendthrift of his powers, and this is probably why he dies in greater numbers. There is no need to put down the greater mortality among males entirely to that artificial instrument of selection which we call human warfare. Nature seems from the beginning to have made men muscularly stronger *yet more subject to disease and death* than the mothers of the race. As a matter of fact, war does not always seem to reduce permanently the male population.

Here we come to a curious theory which will perhaps illumine our own special problem of the extraordinary preponderance of women at present existing in England. In an ordinary way, a long and terrible war results in famine. As a consequence, the women of the race are not so well fed, and several famous men of science have shown that there is a connection between an abundance of nutrition and a preponderance of females, and between a scarcity of food and a preponderance of males.

The Birth of Boys in Poor Homes, and of Girls Among the Well-to-do

The main facts in support of this theory are interesting. Furriers state that rich regions yield more furs from female animals, and poor regions more pelts from male animals. In mountainous regions, where life is hard and food scarce, more boys are born than in the neighbouring lowlands. In Saxony, for instance, when the harvest is scanty, the birth-rate of male children rises in proportion to the altitude of the country.

As a rule, more boys are born in rural districts than in urban parishes, and it is reckoned that this is due to the fact that the diet of people living in cities is richer, especially in meat, than the food of ordinary dwellers in the country. Then, in times of war, famine, and migration, more boys are also born, and it is generally agreed by men who have studied the subject that there are more boys in the poorer families than in the families of the well-to-do. This point has recently been disputed by Professor R. C. Punnett, who calculates that in London in 1901 there were more males born in fashionable districts than in the slums; but his conclusions have not been accepted by Continental observers, who worked with more definite material; and,

WAR, THE MAKER OF WIDOWS & ORPHANS

"THE FOOTPRINTS OF WAR"—FROM F. W. LAWSON'S PICTURE IN THE ART GALLERY, LIVERPOOL

War is one of the factors in the problem of the over-balance of the sexes. It has been estimated that the Napoleonic wars robbed France of eight million lives, and in striking down the father and the bread-winner war destroys the natural means of carrying on the race.

as we shall see, another interpretation can be placed on the facts. It has been found throughout Europe that when the cost of living increases, the number of marriages diminishes. This decrease in marriage results in a decrease of the birth-rate, but a larger proportion of male children are born in these periods of general scarcity of food. With the recurrence of prosperity there is an increase in the number of marriages and births, and the proportion of female children rises, though it never, of course, equals that of the males.

The Great Majority of Women and Girls in the British Isles

Everything thus seems to concur in producing in a highly civilised and pacific community many more women than men, and it seems as though the problem of the very unequal numbers of the sexes, which now troubles the British nation, will become universal as peace and civilisation spread over the world. The figures of the census of 1911 show that there are in the British Isles 1,178,317 women and girls in excess of men and boys. When savage and barbaric peoples are perplexed by an inordinate disturbance of the balance of the sexes, they often resort to war, or strange and degrading marriage customs. A large increase in the male population seems naturally to lead to war; the young men are unable to get wives, and the chiefs and elders are at last compelled to find a vent for their energies by some act of aggression on neighbouring tribes which results in battles. Up to recent times this was a constant source of war in Southern Africa. Moreover, it is probable that a preponderance of young males among the Tartars gave rise to those wild, fierce, periodic explosions of force which disturbed the Mohammedan world, and swept over China, on the one hand, and Russia, on the other, and threatened to overwhelm Europe.

Were the Tartars Impelled by an Overbalance of the Sexes?

The Tartars are indeed the most striking example of a people impelled by an overbalance of the sexes. Living originally, like the natives of Australia, in a parched and desert land, they displayed in a very remarkable way the connection between poor nutrition and a preponderance of male births. Permanent hardships made them a nation of men, and incited them to warlike aggression. No doubt their hard conditions of life tell on the male children more heavily than on the more resistant females; and this serves to reduce the inequality of the sexes; but the general factor seems, as Dr. Westermarck observes, to work toward a predominance of males.

Races with weak passions and little energy of character have been tempted by an excessive number of males to resort to polyandrous marriages, in which one wife takes several husbands. Polyandry occurs chiefly among mountaineers, and it seems to be an indirect result of poor and scanty food, and a direct result of the excessive number of male children produced by the starving rigour of this kind of life. Here, again, the greater mortality among male infants may tend to restore the balance of the sexes, and the monastic system of the Tibetans may work in the same direction; yet, if our present knowledge of Tibetan life may be relied on, the women still remain in a strange minority. Had the Tartars adopted, like the Tibetans, the easier and more degrading solution of the problem, they, too, would have lost their extraordinary virility. They undoubtedly chose, from their point of view, the better part in taking to warlike action. By keeping, on the whole, to the marriage between one man and one woman, they have retained their source of strength, and spread from China to the Crimea. By repeated invasions they have diffused their blood among other nations, and many famous Russian men of genius are partly of Tartar descent.

The Observations of a Traveller in the Seat of an Ancient Civilisation

The problem of an excessive number of girls and women does not seem seriously to have troubled any people in the past. It occurs in a permanent form among races leading an easy life in regions where food is abundant; and it is solved by the custom of one man marrying several women. The natural causes of polygamy, however, seem to be found in only a small part of the world. The famous traveller James Bruce, writing towards the end of the eighteenth century, made some interesting remarks on the subject.

From a diligent inquiry in the south part of Mesopotamia, Armenia, and Syria, from Nineveh to Aleppo and Antioch, he found the proportion to be fully two women to one man. "There is, indeed," he says, "a fraction over, but not a considerable one. From Latikea down the coast of Syria to Sidon the number is very nearly three, or two and three-fourths, to one man. Through the Holy Land, the country called Horan, in the Isthmus of the Suez, and the parts of the Delta unfrequented by strangers, it

is something less than three. But trom Suez to the Straits of Babelmandeb, which contains the three Arabias, the proportion is fully four women to one man."

This region corresponds with the seat of one of the most ancient of civilisations, where, before the days of Abraham, the great fertility of the soil made life pleasant and food cheap and abundant. No doubt in the earliest Biblical times the proportion of the sexes had been gravely disturbed, with the result that polygamy had been widely adopted. A great part of Arabia, however, is wild and barren, and if Bruce was right in stating that there also the number of women greatly exceeds the number of men, the accepted theory of the connection between nutrition and an excess of female births would be exploded. But, as a matter of fact, it is now known that Bruce was incorrect in including Arabia in his statement. Like many other Mohammedans, the Bedouin marries more than one wife when he can afford it, but he is monogamous as a rule, by force of circumstances. As we should expect in so desert a country, the women are somewhat smaller in number than the men, and in ancient times the disproportion was so great that the reverse of polygamy obtained, and one wife often had several husbands. When polyandry was abolished, the Arab became for a time an equal of the Tartar in expansive warlike power. He swept the world from Spain to Persia, and but for Charles Martel he would have become master of France.

TYPES OF A WILD RACE THAT THREATENED EUROPE

The Tartars, of whom these are types, afford the most striking example of a people impelled to wild, fierce explosions of force by an over-balance of the sexes.

The polygamy of the modern Bedouin is only a fashion which he copied from his luxurious neighbours. A warm climate, a fertile and well-watered soil, and an early knowledge of agriculture seem to have made polygamy natural to the peasants around the Nile, the Euphrates, the Tigris, and the shores of Syria and southern Asia Minor. Now and again, perhaps, the balance of the sexes was temporarily restored when one of these great civilisations laid waste the territories of the others, and enforced a more vigorous way of life on the famished and stricken inhabitants. Scarcity of food resulted in an increase of male children, which sometimes enabled the vanquished nation to recover by poverty the position it had lost by luxury. But then came a return of prosperity, and with it a superabundance of women. Conqueror after conqueror has swept down on this fertile region, only to be first weakened and then broken by the natural temptations to a lower morality and an effeminate way of living.

Similar temptation seem to have obtained from an early time among the Chinese, who also possessed the doubtful blessings of a civilisation based on a very ample supply of food. They are also said to be troubled by an excess of women, and yet

they are monogamous as a rule. Whether they practised infanticide to any extent, as some travellers report, is doubtful. It is more probable that they have been saved by their simple way of living, their high morality, and the splendid effects of their system of ancestor-worship. Sons are more necessary to a Chinaman than life itself; for if he does not have a son there is no honour for him when he goes down to the dead. Thus, in China the naturally greater mortality among male children may partly be avoided by the care which the boys of even the lowest class receive from their parents.

The Value of a Complete and Detailed Census of the Chinese People

Unfortunately, we do not yet know sufficient about Chinese life to draw from it any sound conclusions. The people are not numbered and sorted out and classified, as in the census returns of Europe. It is possible that when China is at last reformed, and the people numbered in a scientific manner, all the information now given to us in scraps by missionaries and travellers may be found to be inexact.

Undoubtedly a complete and detailed census of the population of China might help us to solve our own pressing problem of a superabundance of women. If the Chinese, unlike the inhabitants of the Biblical lands, have escaped from the consequences of a settled and plentiful civilisation, they may be able to point out the way to us. Or we may turn for information to the races of India, who are also reported to be inclined to polygamy, but compelled by the natural balance of the sexes to keep generally to one wife. Both the Chinese and the Indians live on much less rich food than we do, and there is a high probability that this is the direct cause of their general proportion in the number of the sexes.

The Key to a Tremendous Human Problem, which may be Found in a Rose Garden

Many men of science who have gone into the matter have come to this conclusion. There is now accumulated a great mass of intricate and difficult scientific research on the subject of the determination of sex, but unfortunately no complete and definite experiment has yet been made. The deeper our men of science penetrate into this mystery of life, the more mysterious it becomes. It seems as though it will be long before we obtain the power over life possessed by certain insects. Bees and ants can perform miracles. By giving a larva richer food than its companions they can transform it from a neutral worker into a great queen-mother. One man of science is inclined even to believe that bees can control the number of drones they wish to produce out of the eggs the queen lays. His observations, it is true, have been strongly disputed; but other researches have been made which have brought to light facts hardly less wonderful.

Everybody who has a garden and tries to grow roses is sadly acquainted with the aphide, the insect which does great damage by feeding on rose bushes. In the summer-time, when food is abundant, it gives birth entirely to female offspring, and only when the cold weather comes are some males born. There can be little doubt that it is not the change from summer to winter that determines the sex of these insects, but the amount of food the parent is able to obtain from the tree at the different seasons of the year.

This is made clear by another experiment made by Professor R. Hertwig, of Munich, one of the most famous of living men of science, who experimented with a tiny little creature, called a daphnia, which hops about ponds and rivers and swamps.

The Little Creature which Hops about Ponds and Swamps, and has a Remarkable Power

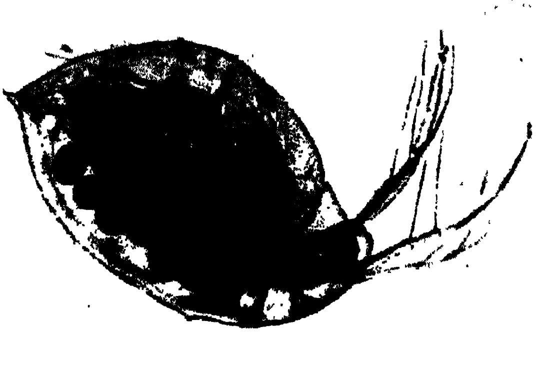
The daphnias were kept in various degrees of warm and cold water, because it was thought that temperature was the deciding factor. In each case those placed in ordinary warm water produced only a certain kind of female offspring, and it was discovered that this result was due to the fact that the warm water was *richer in food material* than the cold water. For when the daphnias were placed in warm but filtered water, they produced as many males as in cold water.

It may be said that aphides and daphnias are a very low form of life, and that conclusions based on examining them do not apply to creatures higher in the scale. This objection has, indeed, often been made by men of high authority. But E. Yung has shown that the frog, which is an animal of complex development, is still a better subject for experimenting on the determination of its sex. Yung fed tadpoles on different kinds of food. When the tadpoles were left to themselves the percentage of females was rather in the majority; the average number was about from forty-three to fifty-seven in the hundred. In the first brood, by feeding one set with beef, Yung raised the percentage of females from 54 to 78; in the second, by feeding

them with fish, he raised the percentage from 61 to 81; while in the third set, when especially nutritious flesh was supplied, the percentage rose from 56 to 92. That is to say, in the last case the result of high-feeding was that there were 92 females to 8 males. When we pass to higher animals, the difficulties of proving the influence of nutrition upon sex are much greater. Yet there are many observations which go to increase the cumulative evidence. Long ago an important experiment was made by Girou, who divided a flock of 300 ewes into equal parts, of which one-half were extremely well fed, while the others were kept on poor food. In the two cases the proportion of ewe lambs was respectively 60 and 40 per cent. Another observer, C. Düsing, has noted that it is the heavier ewes which usually bring forth ewe lambs

Again, this evidence has been disputed, especially by the followers of Auguste Weismann. Weismann is a Darwinian of the extreme school. He will not admit that anything except the selection of the fittest has any influence in the evolution of life. This way of thinking, however, has now been overturned by researches made by students of both animals and plants. Men of science of the new school believe that life is more responsive to every kind of stimulus than Weismann fancied, and they hold that external influences more often mould the various forms of life than destroy all the variations and leave only one to flourish.

Under the influence of Weismann's theory, many men of science gave up the problem of the determination of sex, thinking that it was incapable of being solved; but now that theory is becoming modified, many new and enlightening researches are being undertaken. Professor Hertwig, of Munich, is the leader of the new school. He has attacked the most difficult of all problems—the problem of the cell—and he seems to be working his way toward a solution. One of his pupils, Mr. S. Kowalewsky, published in 1911 a preliminary account of some new investigations in regard to sex determination in animals. After reviewing all previous theories on the subject, Kowalewsky comes to the conclusion which we have maintained in this chapter. He holds that poor nutrition in the female parent is conducive to the production of male offspring, and that rich nutrition is conducive to the production of female offspring. In other words, an abundance of food and a good digestion enable a female parent to store up a great deal of energy, and this she hands on to the race by giving birth to a daughter. We have already seen that girls, in spite of their apparent weakness, have a more resistant constitution than boys; so it is not remarkable that they should be born in greater numbers by well-nourished mothers. Kowalewsky conducted his experiments on guinea-pigs and rabbits, and his researches were extraordinarily thorough. He placed under the microscope the tissues of some of the animals on which he had experimented, he traced the effect of nutrition upon their supply of blood, and he showed clearly in what way this supply of blood acted in producing male offspring when it was poor and female offspring when it was rich. He then went on to examine the actual effects that the conditions of life have on the blood of women, and he showed that these effects would make the Tartars just what they are—a race remarkable for the preponderance of men and boys over women and girls.



A TINY CREATURE WITH A KEY TO A MOMENTOUS PROBLEM

This little insect, called a daphnia, which spends its life hopping about ponds and swamps, gives birth only to female offspring in warm water, where food is plentiful, and only to male offspring in cold water, where food is poor.

It thus seems that we are at last in a way to obtain some knowledge of that mystery of life which from the social point of view is of enormous importance. We are now beginning to be able to see by what means Nature has maintained the balance of the sexes. We have numerous examples in history of wars and other social upheavals, where males have largely suffered, and yet where, within an apparently short period of time, the proportion of the sexes has been re-established. This goes to show

that some mechanism must exist by means of which the number of males and females born is regulated. The sex-equilibrium may be compared to that of a gyroscope, where the greater the disturbance of position, the greater is the force tending to re-establish its natural stand while in motion. The facts regulating the proportion of the sexes must be something of the same type; they are such that, the greater the oscillation in any one direction, the greater must be the restraining force that curbs and neutralises the movement.

The Wild, Destructive Energy of Men who Cannot Find Wives

Nature, however, uses rough methods. When a race is troubled by a superfluity of young men unable to obtain wives, and hard put to it to get a living, a fierce, angry, warlike spirit is born from the general discontent. As a rule, such a race at last explodes in wild, destructive energy; there are often intertribal wars, from which there emerges some great captain, like Tamerlane, who directs the young men from victory to victory over richer nations. Famine and poverty, on the other hand, are the medicines given to nations whose luxurious ways of life are leading to a superfluity of women and to the polygamous marriages which end in making a superfluity of women almost a social necessity. Pestilence has also been one of the terrible scourges whereby nature has driven man back into a naturally monogamous state of society.

It may be thought that at present there might seem to be no balancing force in the civilisation we are now spreading over the world. We are conquering the agents of disease and discovering new sources of food supply, and thus increasing the influences which disturb the equilibrium of the sexes. Instead of going back to a simpler and a harder life, we are becoming luxurious.

The Natural Restoration of the Balance Between the Sexes

An ordinary artisan now has set daily on his table at meals articles of food which kings could not have commanded a few hundred years ago. The standard of living is continually rising, and wages are being forced up to meet the increased cost. Pestilence and famine are practically subdued. The progress in science and machinery makes their abolition certain. So there remains only war, and this, too, is a diminishing menace. Only the most highly "civilised" nations can now destroy each other, for they alone possess the awful instruments of destruction necessary to the purpose; but they are growing too closely connected by commerce and finance and common culture to act towards each other as the Tartar and the Huns acted towards the people they vanquished. Even if one of the great Powers were defeated by a rival, its way of life would not be changed; it might lose some territory, and have to pay heavier taxes for five or ten years in order to discharge the war indemnity, but it would not suddenly be plunged from luxury into extreme poverty. Modern war, therefore, would not serve the purpose for which it seems to have been originally useful.

Yet, in spite of all this, there is some reason for thinking that the balance of the sexes in our country will be restored within a few generations. Nature seems as subtle as she is strong: finding that she cannot maintain the equilibrium by means of the old forces of war and famine, she is employing more unusual means. Among the new economic conditions of our industrial civilisation, none has been more generally deplored than the growth of luxury which leads to late marriages.

The Far-reaching and Unsuspected Effect of giving Woman an Alternative to Marriage

Young people will not begin married life on the small means on which their grandparents began. Perhaps our millions of business girls, factory girls, and servant girls have acquired a stronger spirit of independence. Earning a considerable sum of money themselves, and being thus able to indulge their tastes for some of the showier pleasures of life, they want their lovers to be comparatively well off before they fix the wedding-day. In short, they have *an alternative to marriage*, so they lengthen the pleasantly irresponsible period of courtship.

The young men, too, are also moved by a zest for the amusements of the town. Until they are getting a wage which will keep two in comfort, they do not seriously think of marriage. The best of them struggle and save in early manhood with a view to giving their future wives as good a home as the fathers of the girls were able to establish late in life. No doubt many young couples among the working classes still face life together at an early age; as the young artisan often earns as high a wage as the older men, he is enabled to marry earlier than the men of the middle classes. But the same influences are working throughout the nation, and the working population generally is becoming more pleasure-loving, and putting off to a later period of life the frugalities that follow on marriage.

Now, the older a woman is, the smaller is the store of energy she possesses. It seems as though at about the age of thirty she begins to live on her capital-fund of nutrition, as men do. The fine physique of the modern athletic girl appears to be produced to some extent by the fact that she remains single for a much longer time than her grandmother did. An English bride of thirty, trained in open-air games, often appears as splendid an embodiment of womanly beauty as ever existed in the world, but, as a matter of fact, she is living on her energy, instead of storing it up.

So, by a different and more pleasant road, the Englishwoman arrives at a position similar to that occupied by the hard-worked and under-fed Tartar girl. In other words, she becomes the mother of boys. This is probably the true explanation of Professor R. C. Punnett's surprising figures of the excess of male birth in well-to-do districts of London as compared with the excess of female births in poorer districts. All urban classes are now fairly well nourished, on the whole; so it is only the age of the mothers and fathers that tell; and this age is lower among the London poor than among the professional and middle classes of the population.

The Age of the Mother which Seems to Affect the Sex of the Child

The effect of the modern late marriage in restoring the balance of the sexes was recently discovered by Dr. R. J. Ewart. Here are his tables giving the relation of the age of the mother to the sex of the child.

All Births up to	Males	Females	Males per 1000 Females
19th year..	19	44	659
24th year..	226	264	856
29th year..	437	455	960
34th year..	716	617	1000
39th year..	720	715	1007

If taken between the stated ages, the figures are as given in the following table.

	Males	Females	Males per 1000 Females
All births up to 19th year	29	44	659
From 20th to 24th year inclusive	197	220	895
From 30th to 34th year inclusive	180	162	1111
From 34th year and after ..	155	133	1165

It thus appears that young mothers have a tendency to produce more daughters than sons, while at more mature ages there is an excess of male children. There is the same difference in the offspring of young fathers and mature fathers; so that we can easily see how a self-regulated balance of the sexes is established. In a state of society in which women are scarce, there is a great demand for them in marriage. Therefore they naturally wed early in life, and thereby tend to produce an excess of female children, thus neutralising the condition of things which recently existed. Should the men be in the minority, on the other hand, the women will marry later in life—as is at present the case—and an excess of male children will result from these marriages.

A Natural Tendency which will Probably Put Men in a Majority Again

Thus the natural tendency at the present time is to neutralise the superfluity of women. Such is Dr. Ewart's theory. He has not yet proved one part of it, perhaps—that which makes an excess of women result in raising the mean age of maternity. Happily, another factor, as we have shown, is concurring to this end. The growing independence of a large number of girls who, by reason of their work in factories, households, and offices, have an alternative to married life is now bringing about a general decrease in early marriages.

We may regard the British nation as now being at an extravagant height of female preponderance, but in the natural course of things a more numerical equality of the sexes will be established; and we can probably quicken the natural course of things by helping by every means that lies in our power to save the children of the nation from premature death.

The New State of Things which Would Solve Many of our Social Problems

A high and enlightened standard of morality is very important; and, in so far as education increases one's power of self-control and introduces new interests in life, it also helps to prevent very early marriages, thus increasing the preponderance of male births. If the present rate of progress is maintained, an average marriage rate of from twenty-seven to twenty-eight years might probably produce a population in which boys and men are at all periods in excess of girls and women. When this happy state of things is re-established, some of the most dangerous of the social problems of our age will be solved.

THE HUMAN STREAM POURING EVERY YEAR INTO THE UNITED STATES FROM ALL NATIONS

Mr. Roosevelt has declared his opinion that the American people are committing race suicide, which is his way of saying that in a few generations the United States will be dominated, not by an Anglo-Saxon race, but by a composite race, whose possession of the continent may have momentous consequences for mankind. In some typical American cities two children of "immigrants" are born for every child of "native parentage."

THE NEW MANKIND

The Grave Problem of the Falling Birth-Rate and What it May Mean to the World

WHO WILL CARRY ON CIVILISATION?

If any policy is to succeed it must have regard to the nature of the facts with which it proposes to deal. Above all is this true of eugenics, which has more complicated facts to deal with than any other science. If we desire to improve the quality of future generations, we must know all we can of the manner and degree in which the generations succeed one another. In fact, that is the problem of heredity, but primarily it is the problem of births and deaths and marriages, as we shall see.

The law of the pressure of population taught us that the eugenist must concern himself with the rate and the manner in which populations increase. The natural growth of population depends on the excess of births over deaths. But such factors as emigration and immigration play a most important part, far more important than we realise, for they usually involve change not only in numbers, but also in quality; and there are facts of the birth-rate, as in Ireland, which can only be understood by the study of emigration.

This is the problem, of *vital* imports and exports, which most politicians have yet to discover. But, in the first place, we are bound to study the natural increase of population, which depends upon the fact that, from year to year, the number of births exceeds the number of deaths. We may reckon, for any population, the number of births per annum per thousand of the population, and similarly the number of deaths. These figures will be the birth-rate and the death-rate. Apart from emigration and immigration, the population will increase if the birth-rate exceeds the death-rate, and *vice-versâ*. So far, all is simple.

The normal tendency of all forms of life whatsoever is to increase and multiply. Though multitudes die, more are born. There is no internal limit to the growth of population—except in the strange case of man's volition—and so it grows as far as it can. It is arrested by competition with other forms of life, by lack of food, by over-crowding tending to produce disease, by war in the case of mankind, and by other causes, but normally its tendency is to increase. As the dominant being of the world, able not merely to multiply as far as food will let him, but also to call new food into being, thus multiplying further, man everywhere tends to have a higher birth-rate than death-rate. Hence the growth and pressure of population and half the facts of history.

But man, though unique in his increase, has the lowest birth-rate of any living being in proportion to his size—a qualification which excludes the case of the elephant; and, as Darwin pointed out, the fulmar petrel, though probably the most numerous bird in the world, lays only one egg. These facts suffice to show that no practical or useful understanding of the birth-rate is possible unless we also take into account the death-rate. On the evidence of the birth-rate, man and the petrel ought to be the rarest of mammals and birds respectively, but they are the most numerous—evidently because of their low death-rate. The bird produces only one egg, *but she takes care of it;* and though man is the slowest of breeders, and though an enormous proportion of his offspring fail to reach maturity, yet that proportion is far smaller than in the case of any other species.

These general considerations require statement, simple though they be, because people who do not clearly see the connection between the birth-rate and the death-rate fail to understand how the population of a country may rise rapidly while its birth-rate falls rapidly; and many people suppose that the population of France is decreasing

because it has such a very low and ever-falling birth-rate, whereas the fact is that the population of France just increases. Unless we realise that increase and decrease are dependent upon the ratio of birth-rate to death-rate, of course we shall go wrong. Again, the Germans increase their population by just two babies to our one every year—one of the few most important of political facts—and one finds many people who suppose this to mean that the German birth-rate is twice ours, and many more who cannot understand how Germany comes to have a much higher death-rate than ours. The German birth-rate is really not so very much higher than ours, but Germany's population is far larger, and so the absolute number of births is far greater. This remains true, even though the German birth-rate is now falling with extreme rapidity. As for the fact that the German death-rate is higher than ours, that does not prevent her population from increasing more rapidly if she provides babies enough, as she does, but apparently will not do for long.

A little reading and practice soon accustom us to dealing with these rudiments of the sub-science which is called Vital Statistics; and certainly there is no science of which politicians and the public are more ignorant, and of which the elements should be more widely known and understood.

The Capacity of a Nation to Reproduce Itself

Obviously, a population may increase more rapidly than ever by increasing its birth-rate, or by diminishing its death-rate. The numerical result would be the same, but the composition of that population will be quite different in the two cases, and, so far as progress and eugenics are concerned, the two are worlds apart. To name only one incidental point, the population due to a high birth-rate will be, on the average, many years younger than that due to a lowering of the death-rate. This age-constitution of a nation profoundly affects national temper and policy at any given time, and it still more profoundly affects the national future, for the capacity of a population to reproduce itself depends upon the proportion of young and mature people in it. Anyone who looked at the very low birth-rate of Ireland might be horrified, and would certainly be misled in his conclusions, if he did not realise that here is a population which is largely bereft of possible parents, not in this case by death, but by emigration. These matters of the age-constitution—and not less of the sex-constitution—of a population are vital to our understanding of its real condition and its probable future.

Now, if we survey the whole of civilisation, we find that a fall in the death-rate is a general and continual fact. Very largely, civilisation simply means a falling death-rate—that is, the maintenance of life and the postponement of death, by drainage, sanitation, water supply, protection from weather and wild animals, and so forth.

The Death-Rate that has been Falling from the Dawn of Life

The fall in the death-rate is, indeed, not merely a fact of civilisation, but a fact of all progress in life, as Herbert Spencer pointed out long ago. The death-rate has been falling from the dawn of life, as life has gained upon nonentity and death. Man has by far the lowest death-rate of any living creature; his death-rate falls as he progresses; it is lowest in the highest civilisations and the highest parts of such civilisations, and is highest in the lowest.

Within the last three-quarters of a century the death-rate has greatly fallen in all the progressive countries of the world, and with ever-increasing speed. In recent years the rate of decline has been astounding. It will be still more so when we take infant mortality, the chief item of any death-rate, human, animal, or vegetable, and deal with it as we should. The new figures for Great Britain, provided by the census of the present year, owe far more than has yet been pointed out to the great campaign against infant mortality which was begun nearly a decade ago, and which has been chiefly responsible for the great fall in the general death-rate.

The Right to Live and the Right to Carry on the Race

The fall of the death-rate is a definite and certain accompaniment and ally of progress, and even of eugenics. True, there are those who deplore it on the ground that it involves the survival of many who would be "better dead." Such persons have not grasped the root-idea of eugenics, which acts not by death but by birth, and seeks to replace the selective death-rate of the past and of the animal world with a selective birth-rate. Eugenics disputes the right of none to live, and to live as long as possible. Its unique characteristic is that it distinguishes, as neither the natural world nor barbarism can distinguish, between the right to live and the right to become a parent. The right to live we question in no case, nor do we propose to achieve progress by the restoration of the

primitive method which slew the incapable, the lame, the blind, the weak, and the peculiar. That would be progress backwards, and it is not for the eugenist. The fall in the death-rate is to be welcomed and accelerated, and the utmost is to be done for the prolongation of every human life. Many such lives should never have come into being, but eugenics should have spoken in time. Now it must hold its peace as regards these individuals and the death-rate among such individuals, but must speak as regards the birth-rate among them.

Let it be granted, then, once and for all, that eugenics has no direct concern with the death-rate, but welcomes its decline, everywhere and always. It is entitled to say that such-and-such children should probably be born, and that such-and-such should probably—or certainly in many cases—not be born; but as regards all existing individuals, eugenics has no rights whatever, except to make the most of them. Further, this applies to the whole death-rate among all individuals, the healthy and the diseased, the sane and the insane, the old, the young, and the unborn. And now we can turn to our proper concern, which is the birth-rate, but only if we realise one further fact of great importance.

The Point Beyond which we Cannot Alter the Death-Rate

The increase of populations depends upon the fact that birth-rates exceed death-rates. If death-rates fall, therefore, populations may continue to increase, and may maintain their rate of increase, or slightly raise it, as Great Britain did in 1901–11, even though the birth-rate be falling by leaps and bounds—as it did in Great Britain during that period. We observe this circumstance with satisfaction, and with revived hopes, but our satisfaction is short-lived if we continue to think. For evidently there is a point beyond which we cannot lower the death-rate, and the point is being now approached. True, science may some day abolish death, with whatever consequences for life, but meanwhile we must all die; and even if we all die of old age there must remain an irreducible death-rate. It follows that we cannot indefinitely regard with equanimity the fall in the birth-rate. That fall may and must be compensated for to the utmost by a fall in the death-rate, but in the long run, evidently, death will have its way, and only birth will keep us going.

Now, what are the real facts of the birth-rate? In general, they are precisely parallel to those of the death-rate. Just as we saw in that case, the birth-rate falls as life ascends, being highest among bacteria and lowest among, say, bishops or philosophers. It falls as civilisation advances, and it tends to be decidedly lower in the higher strata of any civilisation. All this was expressed by Herbert Spencer half a century ago, and the subsequent decades have justified him in this, as in many other matters. Onwards and upwards from the dawn of life the tendency has been towards fewer births, fewer deaths, and more living. This is what we should expect if we understand the general theory of Life and its concerns.

The Conflict between Right and Right which is the Tragedy of History

But, unfortunately, in this age-long advance of ours, mankind does not keep in line; and then there is conflict and difficulty, conflict often not between right and wrong, but between one kind of right and another kind of right—which is, as the German philosopher Hegel said, the greatest tragedy of history. The birth-rate falls not equally, steadily, and for the purposes of life, throughout mankind, but unequally, inconstantly, and too often not at all in the service of life, much less of eugenics, but in the service of death and corruption and luxury—which is death to the soul. And, above all, the birth-rate only deals with numbers and quantity, as if all babies—black, yellow, and white, healthy or diseased, born of wise and kind or of unwise and unkind parents—were equal. Hence the birth-rate and its fall is not a simple matter, but one of the most complicated that we can study; and this natural complexity has lately been involved with another, which increases it beyond estimation—namely, the possibility of the voluntary control of the birth-rate and the establishment of a non-sequence between our conduct and its natural consequences.

The Rise of Germany and Japan, and the Fall of Australia and France

These are facts which arouse all manner of prejudice, and divide men into parties, each of which stridently claims the monopoly of morality, and truculently denounces all who do not belong to it. If the Eugenist is to serve his cause, it behoves him to spend long time in preliminary study; and, indeed, he will find the time so long that he will never reach the stage of ill-will, foolish satisfaction, and foolish despair which most commentators upon the birth-rate display.

To assert consequences is one thing, to allot praise and blame without close

analysis is another. If we find the birth-rate of Japan rising, and that of Australia falling; if we find Germany adding some eight or nine hundred thousand to her population every year, and France only a few score thousands; if we find similar contrasts between the native and white populations of South Africa, and between the Dutch and British sections of the white population—then we may say that this policy of control of the birth-rate, nationally considered, is disastrous; or, at any rate, disastrous to national or racial aspirations and identity. But this is very different from the rude and crude comments upon this complicated phenomenon, containing so much right and so much wrong, in which many distinguished amateurs have permitted themselves to indulge. Here let us be scientific first.

If this be our aim we at once discover that, though what we usually call the birth-rate is a very necessary and useful figure, we require another which is only one degree less important. To state that there is no birth-rate in, say, a home for the aged, is not worth doing; and it follows that unless we know, for instance, the proportion of the aged in a population we cannot understand its birth-rate, though we may state it.

The Only Proper Way to Understand the Birth-Rate

If we are to reach the stage of understanding, we must in every case make allowance for the sex and age composition of the population we are studying; and the figure we obtain when we have made these allowances is called the corrected birth-rate, while the other figure is called the crude birth-rate. We can never compare different nations or populations, nor can we even begin to understand—though we can much more than begin to misunderstand—the facts of any population, until we possess both the crude and the corrected birth-rate.

The crude figure has its own evident value, for numerical consequences. Thus, we compare the crude birth-rates of Russia and France in 1850 and in 1900, and we at once understand why Russia is, *numerically*, at the head of the Great Powers in both years, whereas France was second in 1850, and last but one—Italy being last—in 1900. But we require to know much more than numerical consequences. We want to know consequences in quality as well as quantity, and we want to know how, where, and why the changes in birth-rates occur. For these purposes both crude and corrected birth-rates are essential; nor is any more striking illustration of this to be furnished than that of Ireland, "the disthressful country," whose distress is fundamentally dependent on just those matters which politicians have always forgotten, and which Eugenists should teach them to remember.

The crude birth-rate of Ireland is extremely low, and approximately the same as that of France. Yet France has thrown over its allegiance to Roman Catholicism, has restricted its birth-rate to the most extreme degree on record, and now possesses the most striking example of what Bertillon, the great French statistician, calls a "diseased birth-rate."

The Sad Cause of the Low Birth-Rate in Ireland

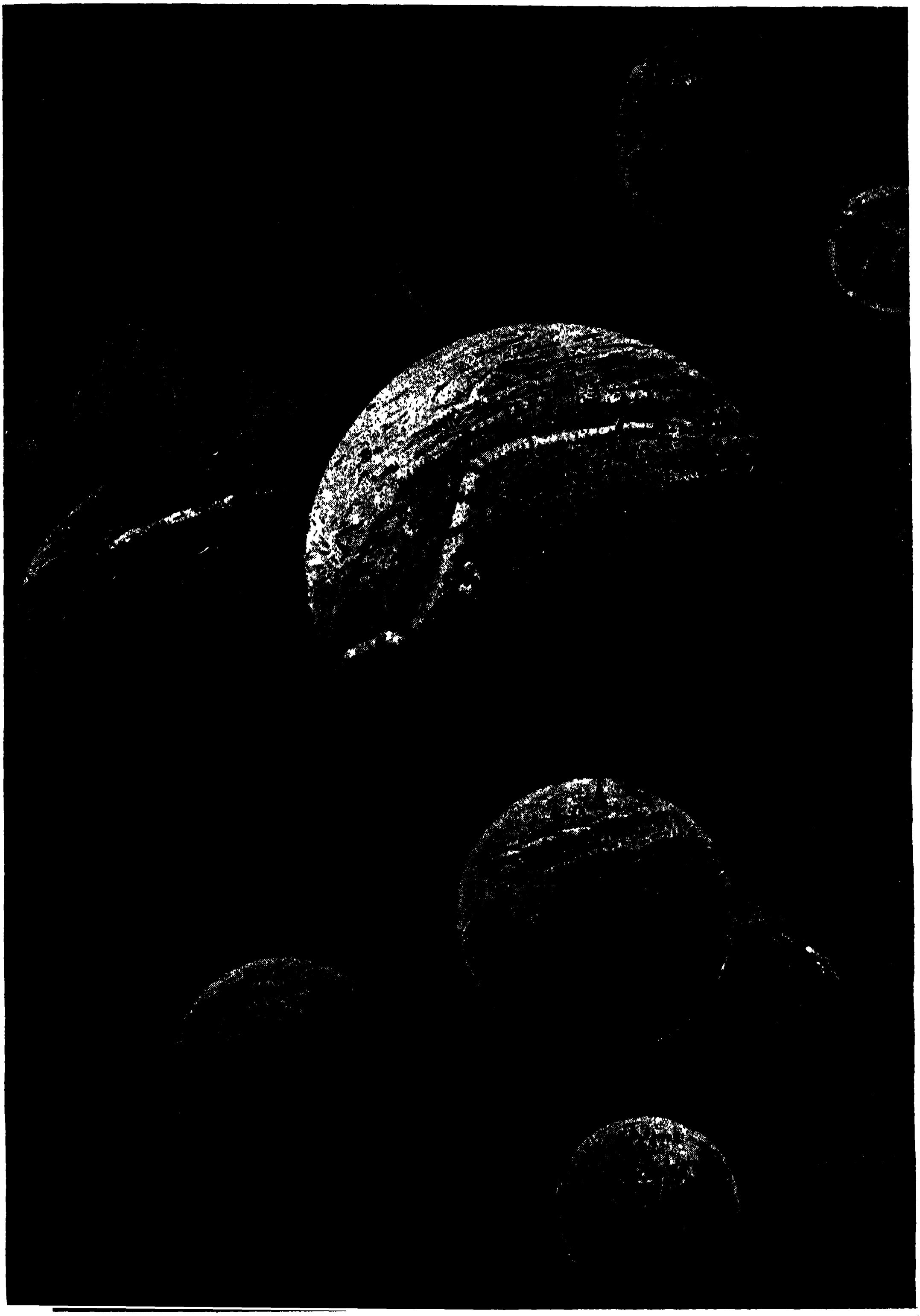
On the other hand, Ireland has not renounced its allegiance to its priests, who speak for a Church which absolutely forbids the voluntary control of the birth-rate; and we know that Irish families are large. Are we to conclude that, though Irish families are large, most of the Irish have undergone some subtle change of feeling or capacity which prevents them from marrying, though similar people in other countries would marry and contribute to the birth-rate? Not at all.

The corrected birth-rate differs from the crude birth-rate in making allowance for the lamentable shortage of marriageable women in Ireland, or, to be accurate, of women from the age of fifteen to forty-five. These, everywhere and always, are the immediate source of the birth-rate of any country or community or class. Now, the corrected birth-rate for Ireland is found to be exceedingly high, at the very opposite pole from that of France, similarly corrected. It is anything but a diseased birth-rate. The Irishwomen who exist, at the reproductive ages, produce many children, *but Ireland is well-nigh bereft of such women.*

The Scientific Remedy for the Distress of the Emerald Isle

Here the study of both crude and corrected birth-rates, and the comparison of both, in two countries, reveal what the crude birth-rate alone not only fails to reveal, but completely conceals. And thus, while France and Ireland both have disastrously low birth-rates, and would both be better for their raising, totally different remedies are required in the two cases. The French require something to persuade them to produce children. The Irish require something which induces or enables a larger number and proportion of young and mature women to remain in Ireland. That

SEATS OF VAST POPULATIONS



These globes represent the comparative sizes of the chief cities of the world at their last censuses, and these figures show the population of each at that time: London, 7,252,963; New York, 4,766,883; Berlin, 3,712,000; Paris, 2,846,986; Vienna, 2,030,850; St. Petersburg, 1,870,000; Constantinople, 1,200,000; ancient Babylon, 1,200,000; Rome, 575,000; Madrid, 571,539; Athens, 270,000; Jerusalem, 80,000.

remedy, so far as the Eugenist is concerned, may be Home Rule or Coercion, or anything between them, but, whatever it be, it is the remedy for Ireland.

Before we leave this question of the difference between crude and corrected birth-rates, two more points are worthy of note. One is that the fall in the birth-rate and the fall in the death-rate, which characterise the life of modern populations, are making the world grow older, in a new sense.

The New Sense in which the World is Growing Older

The average age of the existing population at any given moment is much older than it used to be. Not only does this affect national conduct, but it is bound to react unfavourably on the birth-rate, by increasing the proportion of elderly people, who cannot contribute to it. Hence the fall of the birth-rate promotes a further fall.

The other point has regard to the most important case of Australasia. Here we find a very low and falling birth-rate, in a physical environment which invites an enormous increase of population. But the sex-constitution of the existing population shows far too high a proportion of men, as in Ireland, to that of young and mature women; and thus the corrected birth-rate does much more credit and justice to Australasian women, just as we saw in the case of Ireland. Plainly the remedy, or one great remedy, is the increase of the number of young women in Australasia.

The international aspects of the fall in the birth-rates of civilisations, high and low, have been alluded to, with various notable instances, already. But the national aspects of inequality in this fall are no less important. The new facts of South Africa may, or may not, suffice for those who own the same flag and loyalty. But our American cousins have a problem of their own.

The Grave Peril of Anglo-Saxondom Across the Atlantic

It is not merely the problem of the negro race and its increase, which corresponds to our problem of the rapidly multiplying Kaffirs of South Africa. It is also the problem of the comparative birth-rates of native-born or so-called "Anglo-Saxon," and immigrants—a problem which corresponds to that of British and Dutch in South Africa. Recent American statistics entirely justify the view of ex-President Roosevelt, that the "American people" is committing "race-suicide." That is to say, the birth-rates of "natives" and immigrants in some representative American cities are found to bear the ratio of one to two. In a word, the American people stringently practise voluntary control of the birth-rate, and the immigrants do not. In only a few generations this process, if continued, will necessarily mean that the United States are inhabited and dominated not by a race of chiefly Anglo-Saxon and North European origin, but a race of South European, Mediterranean, Jewish, and even more Oriental origin. Now, this difference cannot be regarded as other than momentous and crucial for the destiny of civilisation upon the North American continent; none the less if French and Southern blood similarly multiplies more rapidly than Anglo-Saxon blood in Canada.

Evidently the time has come when the declining birth-rate must be subjected to the closest possible analysis. The time for condemnation or approbation is far distant, but more knowledge is required at once. What are the essential causes of the fall in the birth-rate?

Such causes may be various, and recent study, notably that of Dr. Arthur Newsholme, has gone far to elucidate them.

Some Notable Causes of the Decline in the Birth-Rate

We may cautiously, not positively, dismiss the theory of a genuine decline in parental capacity. The fall is far too sudden, and the details of it far too definite, for such a view. But caution must be asked for in this matter, since it may be that, in many cases, the modern view of the education of girls has led to a real incapacity for that motherhood which the fashionable girls' school so entirely despises.

A second cause of the fall in the birth-rate is not negligible, and is wholly satisfactory, but is only small in extent. This is the fall, so far as our own country is concerned, in what is called the illegitimate birth-rate. The fall here is greater in proportion than within the bounds of marriage, and will doubtless continue. Considering the customary fate of the unwanted baby, and on all other grounds, this factor of the decline in the birth-rate is to be welcomed.

A third cause of the declining birth-rate brings us still closer to the question of the marriage-rate, which we began by referring to as part of our inquiry. The general tendency in our time is for the marriage-rate to fall, partly because of the increasing number of elderly persons in the community, but chiefly because of the increasing age of marriage in both sexes. The growing practice of marrying later in life will evidently

be a factor in the fall of the birth-rate, and the factor has to be estimated. The rise in the marriage age is hitherto so slow and slight that this factor of the falling birth-rate is of very little importance now. It may prove to be of much greater importance in the not distant future, however, when we may expect the marriage-rate to show a much greater decline, and the average age at marriage to increase still further. The reader will understand that here we are simply stating facts and tendencies, and not appraising them.

increased age at marriage, nor to any failure of vital power. It is a voluntary, deliberate control of the birth-rate, exercised by married people. It is clear that the Eugenist has no choice but to admit the right of married people to determine the size of their families. The Eugenist teaches that parenthood must be made not, as at present, almost the least responsible, but the most responsible, because the most momentous, of all acts; and therefore he has no choice but to prefer deliberate, responsible parenthood, and none other, to that which is in-

THE COMING OF ARTHUR—FROM THE FINE IMAGINATIVE PAINTING BY MR. J. WALTER WEST

"And down the wave and in the flame was borne A naked babe, and rode to Merlin's feet, Who stoopt and caught the babe, and cried, The King!"

The fourth cause of the declining birth-rate is the main cause; and while we are bound to note the others and estimate their consequences, this it is that is now making history, and will make history much more. The decline in the birth-rate in this country began in 1876, much earlier in France, much later in Germany, and it is quite clearly due to voluntary control.

The fall is thus mainly a fall in the legitimate birth-rate, due not to a reduction in the number of marriages, nor to the

distinguishable from the practice of the lower animals. So much must be stated to avoid misconception. But our immediate duty is not praise or blame, assent or dissent, but to find out where this voluntary control of the birth-rate most obtains, and what will be the consequences.

For instance, is it eugenic, involving eugenic selection of the worthiest? That is to say, is it the persons who know themselves afflicted with transmissible disease, or addicted to drink, or related to insane

individuals, or otherwise unworthy or dubiously worthy for parenthood, who decline to have children ?

Or, on the contrary, as most critics assert, is this fall in the birth-rate differential in the wrong direction, against the principles of eugenics? That is to say, is it the improvident, uncontrolled, irresponsible, ignorant, defective members of the community who continue to produce children—children who will, on the average, be like their parents, while the thrifty, thoughtful, self-controlled, intelligent persons decline to have children, and thus produce not only the fall in the birth-rate, but a national degeneration, since only the inferior stocks are left to create the future ?

Two children are added to the population of Germany for

Every one child added to the populatio of Great Britain.

The most astonishingly confident answers have been returned to these questions, in the absence of anything like the knowledge which would alone permit us to answer them at all. We do positively know a few facts; but only until the returns of the last census have been fully analysed shall we be on the way to knowing what we should. The last census provides information as to marriages and births which was never asked for before. In fifty years it will be invaluable, because succeeding censuses will combine to show what is happening. We ourselves, having no earlier facts with which to compare these new ones, must be patient and work for the future—which is indeed the business of the Eugenist—just like the astronomer who notes stellar changes to which only the twenty-fifth century can find the key.

THE CHILDREN OF THE EAST END, WHERE THE HIGHEST BIRTH-RATE IN LONDON IS FOUND.

The new facts definitely known are that the fall in the birth-rate is marked in the middle-class; has begun to be no less marked in the artisan class, and is not to be found at all among the defective and feeble-minded section of the community. In general, the birth-rate is high where material prosperity is low, and *vice versa*. In London, for instance, we lately found the highest birth-rates in the East End, with high death-rates, too, and the lowest birth-rate in Hampstead, which also has the lowest death-rate. Whatever, therefore, be the real facts as to the hereditary worth of the babies born in different classes, it is clear that most babies come where there is least room for them. Since eugenics is primarily concerned with births, we shall never leave this subject; and it is evident that many of these observations raise vital questions which require to be answered. But the primary facts must be stated first; and since the birth-rate is not only the lowest on record in every succeeding year, but will assuredly continue to be so for many years to come, it is high time that we should begin to think soundly and seriously of this chief omen of our present national life.

ALL THINGS ARE CHANGING

The Universe of To-day is not the Universe of To-morrow—'Nothing is Constant but Change'

EARTH WILL NOT PASS THIS WAY AGAIN

WE have surveyed the outwardness and the inwardness, the unity and the persistence, of the universe, and almost all the while have inevitably spoken and thought of it as constant, and of existing things as having ever been in the past, and as being destined ever to be in the future, what they are now. We have now to learn the difficult lesson that the universe of to-day is not the universe of to-morrow, that "All Things Flow," as the Greek philosopher Heraclitus declared two thousand five hundred years ago, and that "Nothing is constant but change."

It is a difficult lesson, because it seems to contradict the major facts of experience. The firm earth seems stable in its rhythm, year succeeding year, and season season, but the earth has never twice in its history been in the same place—we shall never pass this way again. The sun seems constant enough, but the sun is never twice the same, and will be smaller to-morrow than it is to-day—though whether hotter or colder we are as yet unable to say. The truth is that every moment in the course of things is unique, exactly because all things are upon a course, or "in flux," to use the old phrase.

There are, indeed, two opposed views of things, which extend from the stars to the very doings of mankind and of individual men. They have been conveniently termed the *static* and the *dynamic* view. The static view—which, in English, is the "standing" view—sees things in a stationary condition, and recognises in all apparent change a brief rhythm, which quickly restores things as they were. This is the view of the vast majority of mankind until our own time, the exceptions, such as Heraclitus, being but the choice and master-spirits of their age. A certain quality of the mind which we may call its inertia induces a bias in favour of the view that laws and creeds and theories and institutions and customs are either final or can be made so. Probably men incline more towards the static view as they grow older, and sapiently wag their heads when youth opines that abuses may not last for ever, or that we do not necessarily have to take the world, or at any rate leave the world, as we find it.

The doctrine of universal evolution implies the unity and persistence of reality, but it declares that the phenomena or appearances of reality are inconstant and fleeting. It declares a dynamic or forceful view of things, which sees them impelled from within, or from below, in such fashion that the present is always novel and unique, the child of the past, and the parent of the future. The static view maintains that history repeats itself, an assertion which does indeed recognise and express the uniformity of Nature; whereas the dynamic view declares that history never repeats itself; that, as Heraclitus put it, "you can never step into the same waters twice."

This doctrine of universal and orderly change has been often expressed as a law of progress; and it particularly behoves us to beware against this misinterpretation of evolution, which we find especially rife in that part of the theory which concerns itself with life and is called organic evolution. Since evolution has resulted in progress in the world of life, as we ourselves exemplify, many suppose that evolution and progress are synonymous. This is to ignore, in the realm of life, the facts of degeneracy and parasitism, which are as much facts of evolution as are the facts of progress. It is to forget that suns and systems of suns grow cold as well as hot, and that systems of thought, once vital and glowing, alike decay. All these are facts of the universe;

and if evolution be a universal truth, they are facts of evolution.

It is known to very few students that the word "evolution" was introduced, in its modern meaning, by Herbert Spencer, in 1857, precisely because the word "progress," which he had formerly employed, was found to be inadequate as his studies proceeded. Yet more than half a century later, though the word has become popular, we still hear it employed, on all hands, as if it meant progress, and as if it certified all changes and forces of inorganic or organic Nature to be pressing "upwards and onwards."

But if our view of the universe is to be sound, we must understand what we mean, how much and how little, when we speak of universal evolution. We mean that all things whatsoever—one exception, were there one, would be ruinous—are subject to change. This change may be fast or slow, obvious or subtle, catastrophic or gradual, and it may make for what we call progress, or for what we call retrogression, or it may be outside any of our ethical judgments and have to do merely with, say, the shapes of atoms, but it is change, nevertheless, and that is what evolution means. But that is not all.

IMMANUEL KANT, AUTHOR OF THE NEBULAR THEORY OF THE WORLD.

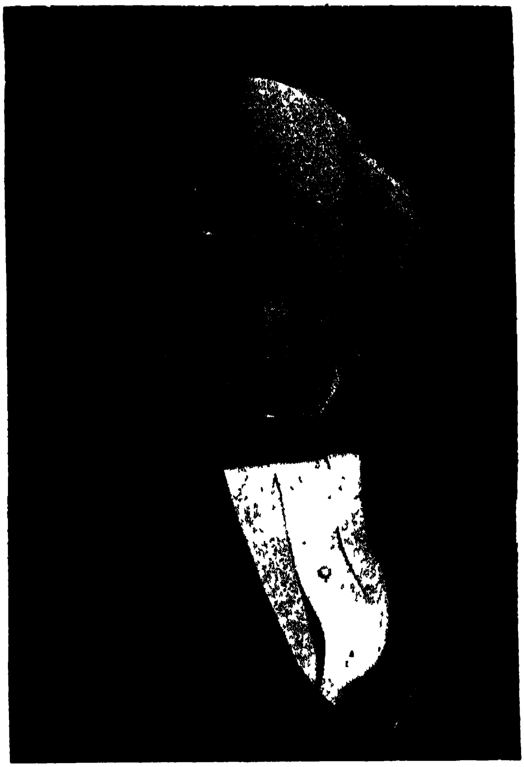
It was Kant, the German philosopher, who founded the theory of the solar system having been derived from a nebula, or fire-mist, yielding planets in the process, as our frontispiece suggests.

Whenever we see change in process, we fear chaos. It may only be that our sitting-room furniture has been rearranged, or that the metric system has been substituted for more primitive modes of reckoning, or that the franchise has been extended—it is enough to make us fear that "chaos is come again," or, in the modern phrase, that the "end of all things" is at hand. It is therefore necessary to remember that evolution is not only change, but ordered change. Chaos will not come again, because there never was a chaos but in seeming. Happenings will always continue, for that is what evolution asserts, but whatever happens will happen according to law, for that is what evolution also asserts. It will not necessarily happen according to any particular law, such as the law of gravitation, for that is itself a product of evolution, and there is no reason why further evolution should not supersede it. Indeed, the doctrine of evolution will require to be remembered and allowed for when we are inclined to speak somewhat superstitiously of the "laws of Nature." But, though we cannot assert that any particular law or mode of action of the universe always has been, and always will be, its mode of action, we can assuredly assert that the law of universal causation always has been and always will be. There may be higher or lower types of cosmos, but chaos never.

In general, we may perhaps agree with Herbert Spencer in discerning two modes of action—from the simple to the complex, and from the complex to the simple. Thus, when a couple of germ cells become a human being, or when a nebula becomes a solar system, we discern typical evolution from simple to complex; when a couple of stars collide, and form a scarcely coherent nebula, or when a corpse is reduced to dust and ashes, we discern the opposite phase of evolution, which is sometimes called dissolution. It has to be realised, however, that when we say "simple," we should rather say "apparently simple," for the fact that the simplicity is only apparent is demonstrated by the subsequent complexity. A tiny speck of protoplasm becomes a complex human body, a shapeless cloud of matter becomes a solar system; and the lesson for the wise is that within and under the simplicity there are forces as complex as their ultimate result.

The doctrine of universal evolution stands definitely opposed at every point to the doctrine of "special creation." The statement is simple enough, but it is almost always misunderstood. We are here on the plane of science, which deals with phenomena or appearances. We are not dealing with ultimates. Evolution, as Lord Morley observed many decades ago, is not a force or a cause, but a law—that is, a statement of a mode of alteration of the universe. Unfortunately, people constantly tend to make a fetish of it, and suppose it to be a cause—a cause which, having now been discovered, disposes of any necessity for a belief in a "first cause," or in anything beyond phenomena. This is thoroughly vicious, and thoroughly unscientific, because it is part of science or knowledge to know its own limitations.

If, instead of evolution, which indeed only means unrolling, we spoke of ordered change, no one would fancy that the doctrine of ordered change answered the ultimate questionings of the human mind. All science to-day is evolutionary; we "think in evolution." The doctrine of ordered change must necessarily pervade and be assumed in every section and every page of such a work as this, but that is merely to say that we accept the view of order and cause and endless events and bringings forth as the mode and being of Nature; and if anyone should fancy that this view is atheistic or materialistic, he may be referred to the last paragraph of "Origin of Species," in which Darwin declared the grandeur of this view of the Divine method of action. Evolution is none other than a doctrine of continuous and everlasting creation, substituted for the doctrine of creation once and for all.



HERBERT SPENCER, WHO FIRST DEVELOPED THE PLAN OF EVOLUTION

It was Herbert Spencer who, over fifty years ago, first used the word "evolution" as describing the processes of natural development. "All things flow, and nothing is constant but change," may well be said to express the ancient meaning of this modern word.

Our business now is to survey the various parts and aspects of the universe in which the doctrine of evolution is illustrated, and in which its doings may be witnessed.

Historically, the doctrine of evolution in the heavens, commonly called cosmic evolution, was the first in modern times to win anything like consideration. In his young days, the German-Scottish philosopher Immanuel Kant outlined a theory which explained the solar system as having been derived from a nebula, or fire-mist, which shrank and cooled and twisted, and yielded planets in the process. Not very much later, biologists in France and Germany suggested that the theory of special creation, as applied to the animal world, must yield to a theory of the origin of species by "descent with modification."

In the middle of the nineteenth century neither of these doctrines found acceptance, and the reason is in each case a highly interesting one. So far as concerns the nebular theory, suggested by Kant, and elaborated by the French mathematician Laplace, advances in telescopic astronomy had sadly discounted it. The newest and largest instruments had succeeded in penetrating space to such an extent that many supposed nebulæ had turned out to be not nebulæ at all, but closely aggregated clusters of stars. The inference was that further developments of the telescope would resolve more nebulæ into star-clusters, and that, if we could see clearly enough, there would be no nebulæ left, but only more or less distant and closely clustered masses of stars. Plainly, the nebular theory breaks down if there are no such things as nebulæ; and the marvellous work was yet in the womb of time whereby it was found possible to demonstrate the existence of truly nebulous and gaseous matter in the sky, and to distinguish these real nebulæ from star-clusters, irrespective of distance.

If the theory of cosmic evolution was in a bad way, no more could be said for that of organic evolution. Its most distinguished advocate, the French naturalist Lamarck, presented a theory of the origin of species which was inadequate and unsatisfactory. Its truth was very doubtful, and it could only explain a tiny fraction of the facts even if it were true.

The Master-Mind of Herbert Spencer which Appeared when the Hour was Ripe

In one direction, however, the case of evolution seemed more promising. The British geologist Sir Charles Lyell gave reasons for believing that the history of the earth's crust was evolutionary, or, in the clumsy word of the period, *unifomritarian*, as contrasted with the generally accepted *catastrophic* view, which attributed the various layers of the crust, and their various deposits of fossils, to a succession of catastrophes, followed by special creation of new forms of life.

The hour was ripe for a master-mind, and Herbert Spencer was equal to the task. He sketched forth, in 1857, a plan of universal evolution, which in succeeding decades he elaborated in his "Synthetic Philosophy." It is fair to say that every substantial thing for which he contended is now granted; men think in his fashion and often in his own terms while supposing that they are refuting or exposing him. Our present business is to survey the doctrine of universal evolution, of universal and orderly change, as it is accepted now by the scientific mind. With whatever labour, it must be made plain that this theory applies everywhere. It is a statement of the universe, and cannot admit of any exception whatsoever.

The Grotesque and Ignorant Way in which Men Use the Word "Evolution"

The use of this great and glorious word "evolution" to mean that man is descended from the chimpanzee is ignorant and grotesque; its use to mean the theory of Darwin that species have originated by natural selection is scarcely less so; it must not be used to mean evolution in the living world, which is properly described as organic evolution; it is only properly used when, in reference to any part of the universe, it is used with the appropriate adjective in front of it.

Lastly, evolution is an assertion of a general fact of Nature, and it is not an attempt to explain that fact. We may have various theories of evolution, and they may be right or wrong, but the statement of evolution remains. This point is highly important at the present time, when long-accepted theories of certain aspects of evolution are being largely modified or abandoned. The opponents of science suppose that the doctrine of universal evolution—which is as simple and direct a statement of fact as, say, the doctrine of the evolution of the motor-car within the last decade—ceases to be valid unless particular theories invented to explain it can be upheld. The confusion is between two totally different things—description and explanation. Evolution is description; indeed, what we call history is just part of universal history, which is evolution. The historian, as a rational being, cannot refrain from attempting to explain the facts which he describes, but the facts remain though the explanation may be inadequate. Similarly, the fact of cosmic evolution remains, though no one now accepts Laplace's explanation of it. Similarly, also, the fact of organic evolution remains, though we now know that Darwin's explanation of the origin of species was far from adequate, and requires to be modified and supplemented by a new theory which has only just been appreciated.

Universal Evolution that Embraces Men and Suns and Worlds and Institutions

These facts may be arranged under various heads, in terms conveniently borrowed from the French philosopher Comte. When we speak of universal evolution, we may recognise it on three planes—inorganic, organic, and super-organic. Inorganic evolution is concerned with the changes of matter, apart from life. Practically, it resolves itself into cosmic evolution, of which the changes in the crust of a cosmic object—such as the earth—are a part; and into atomic evolution, a term which explains itself. Organic evolution is obviously concerned with organisms, plants, and animals. Super-organic evolution concerns itself with something higher than organisms, with evolution in the realm of mind and of human society, of institutions, of art, of thought, and of morals. It was Spencer's supreme merit to survey evolution in all these forms and aspects, and to see in all of them a unity and principle and a community of plan, since suns, atoms, living beings, societies, are all part of the universal whole, and partake of its nature.

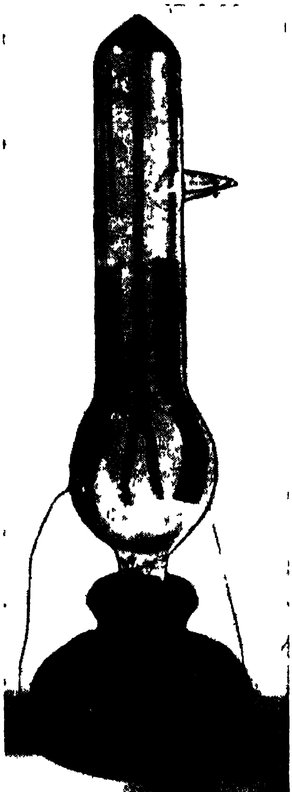
Many of these aspects of evolution are necessarily considered elsewhere in this work, the very plan of which is evolutionary, as the plan of such a work in our time was bound to be. The idea of evolution

"All the epochs of the past," says the Professor of Modern History at Cambridge University, "are only a few of the front carriages, and probably the least wonderful, in the van of an interminable procession." In this picture the artist has tried to express this idea graphically

is implied in a sequence which begins with the universe at large, and passes from earth and life and man to society and its future. Such a scheme is inevitable to-day —it could not have presented itself to anyone's mind a century ago. Thus the particular portion of inorganic evolution which concerns itself with the earth's crust is considered in its place; it is one with modern geology. The part of organic evolution which concerns itself with the history of man is similarly considered, as is that which concerns itself with his possible destiny—a destiny to which only the principles of evolution can guide us. Organic evolution in general is part of the problem of life; and the greater part of super-organic evolution has to do with the mind of man the individual, and his mind as it expresses itself in industry and in society. All these are parts of universal evolution, for they are indeed parts of the universe—so comprehensive is the title of the present section!

But the two most strictly universal aspects of evolution are not treated elsewhere, and demand our further study here.

Cosmic evolution now reckons with nebulæ as facts. This is one of the most important demonstrations of modern science. When Herbert Spencer maintained, against all the astronomical authority of his time, that the nebulæ *were* nebulæ, he could do no more than argue from such facts as their distribution, and from probability. Later, the analysis of light altered the nature of the argument in final fashion. If the light of a glowing gas be examined through a prism—as through the instrument called a spectroscope in the process called spectrum analysis—we find that the spectrum of the light, thus split up and spread out for our observation, consists of a series of bright lines, with dark spaces in between. On the other hand, the spectrum of the light produced by a glowing solid body is an unbroken band of colour. Technically, the first kind of spectra are called discontinuous, and the latter continuous. Applied to certain reputed nebulæ, the spectroscope shows that their spectrum is discontinuous. These are therefore true nebulæ, clouds of glowing gas, not clusters of stars too distant for the telescope to resolve.



YEARS OF ENERGY

This instrument, called a radium clock, displays energy in the form of motion, which is said to have the power of going on for 30,000 years before it can be exhausted.

This is not all. So far from being rare and remarkable objects in the sky, nebulæ are common. They are found in all parts of the sky. We have reason to believe that there are multitudes of dark nebulæ, just as we know that there are multitudes of dark stars. Further, scores of thousands of known nebulæ possess a characteristic and peculiar shape, in virtue of which they are called spiral nebulæ. It can be shown that nebulæ of this form exist in immeasurably larger numbers than could be accounted for by chance. Closer study of the spiral nebulæ shows that, in many instances, more or less solid bodies, which we can only call stars, are condensing in their substance. Many such stars are to be seen, indeed, not only in the spiral nebulæ, but also in the nebulæ of irregular form, such as the colossal example which is known as the great nebula in Orion.

In many instances, also, the telescope shows us nebulous stars, whose core we must call starry, but whose envelope is nebulous. Here, then, is definite evidence not only that nebulæ exist, but that they undergo changes which are somehow connected with the origin of stars or suns. We survey the heavens, and find evidence of stars in the making, in all stages, young and old, chaotic nebulæ, spiral nebulæ, nebulæ with incipient stars, nebulous stars, ordinary stars, dark stars. We need go no farther to be assured that cosmic evolution is a fact. Be it observed that in this survey of a universal truth we are not attempting explanation, but are giving the first place to description. Nebular theories come and go—the problem of explanation is almost insoluble—but the fact of cosmic evolution is as clearly proved by a survey of the heavens as the fact of human growth is proved by the observation of human specimens ranging from infancy to old age.

Since Spencer's day astronomers have gone much farther to demonstrate the details of this aspect of inorganic evolution.

We commonly speak of "the stars," as if they were all alike, save in size and brightness. Yet we have only to use our eyes on any fine evening to observe the contrast in colour between such intensely white stars as Sirius or Vega, and such a red star as Aldebaran; and we may reasonably guess that our own particular star, which we call the sun, would rank as yellow—somewhere in the scale between the whiteness of Sirius and the redness of Aldebaran.

The Stars that have their Ardent Youth, their Steady Prime, and their Fading Old Age

Now, a poker may be white-hot, or yellow-hot, or red-hot, or dark-hot, or dark and cold. In this case there is evidently a relation between colour and temperature; and if we imagine a star to possess a certain original amount of heat, which it loses by radiation, we may imagine its colour to change, throughout untold ages, so that at its hottest it would be white, in its last stage of visibility it would be of a dull red, and, later, though no longer emitting light, it would emit heat, like a dark-hot poker, until, finally, it became both dark and cold.

The great work of Sir Norman Lockyer and many others has taught us that this is something more than a mere fanciful parallel. The stars have their history and destiny, their ardent youth, steady maturity, fading senility, as we have. Doubtless the facts are nothing like so simple as we used to suppose, neither as regards the origin of stars from nebulæ, nor as regards the history of individual stars. The case of the poker is simple, but the case of a star which contains many and various elements is complex. It may be that a star has a period of ascending temperature as well as a period of descending temperature; and the discovery of radium, with its generation of heat, has not lessened this possibility.

The Theory Set Up by Herbert Spencer Against the Opinions of His Age

Most notable in this connection is the fact that different elements are found in different types of stars, light elements in certain stars, heavier elements in other stars. There is good reason to suppose that the two great aspects of inorganic evolution, which we have called cosmic and atomic, are not merely to be set in contrast, the one dealing with inconceivably gigantic, the other with inconceivably minute objects, but are to be put into relation, for it may be that they proceed together, and depend upon one another.

No one was prepared to believe in atomic evolution in Spencer's day. The accepted dogma regarded atoms as the most perfect examples of "special creation," having upon them, as a celebrated student remarked, "the stamp of the manufactured article." If universal evolution was true, however, Spencer could not accept the chemists' teaching, nor did he. But it was not until the present century, just before Spencer's death, that the discovery of radium provided us, in the realm of the atom, with something which answered to the Spencerian formula of evolution as exactly as if that formula had been framed to fit the case. What the details of atomic evolution are we only know as yet in small part, and we are much farther from any explanation of its processes. More will be known of this fundamental part of universal history when this section is brought to an end than now, for our knowledge accumulates with extraordinary speed. But already we know something.

We know, for instance, that an idea suggested by a Greek thinker, more than two thousand years ago, is true. Democritus, the first atomist, had a pupil who argued that all manner of atoms would tend to be formed by Nature, and that only those which suited the conditions of their existence would survive.

The Grandchildren in the Realms of Atoms, who Win in the Struggle for Endurance

This is the idea of "natural selection," as Darwin called it in reference to living beings, applied to atoms. On this view, the eighty-odd elements that we know, each made of a special kind of atoms, represent the survivors, the most stable forms, from among a multitude which are always making brief and unsustained bids for existence.

Enough is already known of the facts of radium and certain other elements to prove that this ancient idea is true. In our time and place in the universe, atomic evolution is all, so far as we can discover, in the phase which consists of large and complicated atoms breaking down and yielding smaller ones. An opposite phase, in which large and complicated atoms would be formed by the union and deft weaving of small ones, may be imagined; and it is scarcely too daring to suggest that some of the astronomical observations of Sir Norman Lockyer seem to consort with such a process. But for us, at any rate, atomic evolution is in the phase represented by radium. It is now certain that radium is the descendant, probably the grandchild, of the element uranium, the atom of which is still larger and heavier. The radium atom goes through

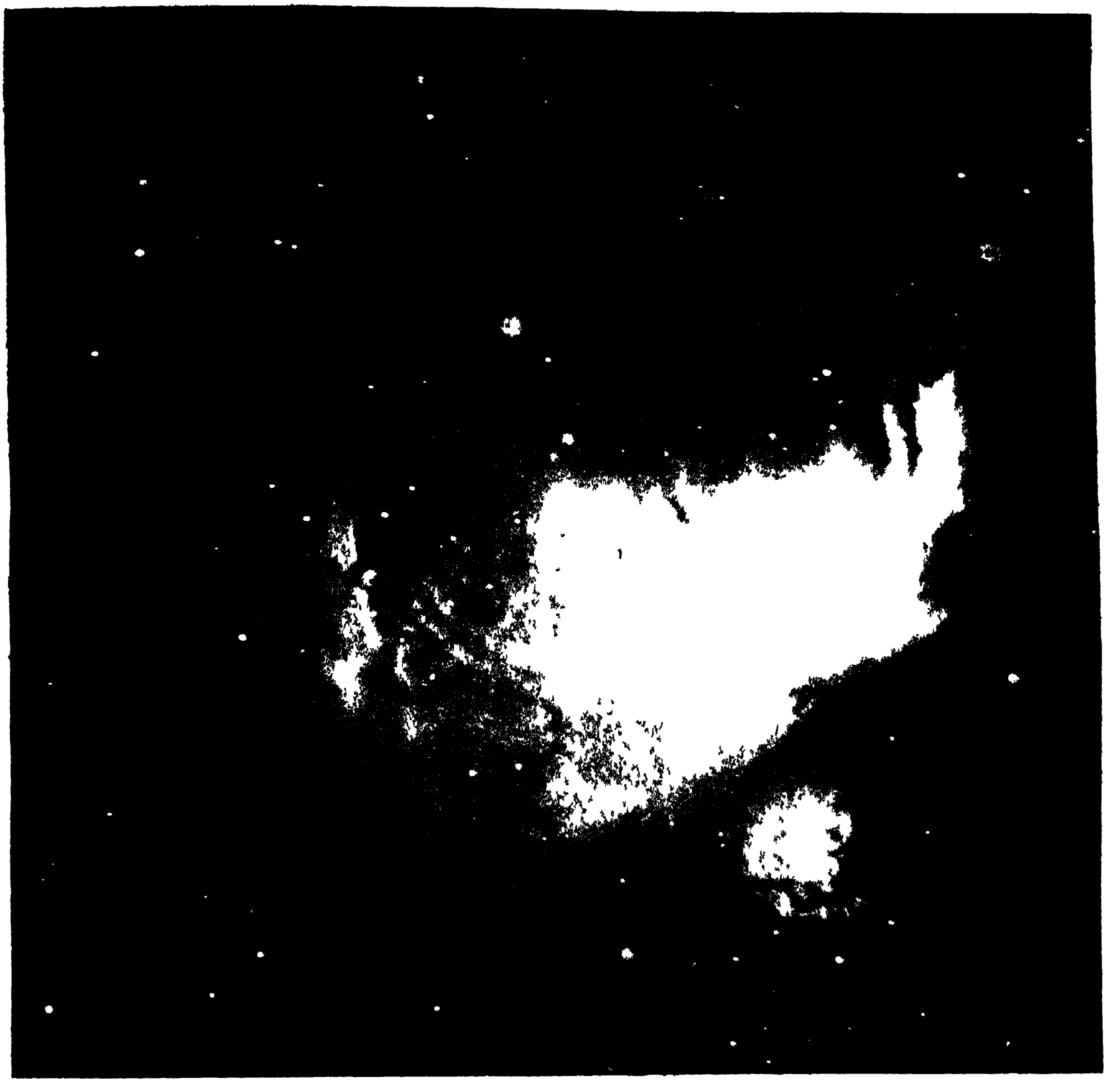
THE BEAUTIFUL CORE OF THE GREAT NEBULA OF ANDROMEDA: A VAST GLOBE OF GLOWING GAS FROM WHICH NEW WORLDS EMERGE

From masses of glowing gas such as this our solar system must have evolved, and from this mass itself new worlds are still evolving. This photograph was taken through the famous Yerkes telescope; the one opposite was taken at the Lick Observatory

a number of stages in its further evolution, but most of these are highly unstable, and can exist for only very short periods, even to be counted in seconds. We thus learn that there are unstable atomic forms, which are ousted in the atomic struggle for existence, and yield to stable forms, which may endure for thousands or millions of years, though in them also change is at work. The known atomic forms which go to the making up of the elements that we know represent the stable—or, rather, the relatively stable—forms of atomic architecture.

If we trace the successive transformations of the radium atom, we find that it yields atoms of a wholly different element, called helium, and that the last dull stage of this most brilliant of elements, well named radium, is represented by the atoms which we know as making up the element called lead. These atoms are highly stable, and what happens next to them we do not know; but it is an amazing achievement, within a few years, to have traced the history of one line of atomic evolution from uranium to lead, through a host of intervening stages, certainly including radium, and possibly including silver.

The thinker, as usual, has the laugh of the mere manipulators. Spencer was right: atomic evolution is as much a fact as organic evolution. It is probably the most fundamental form of all evolution, upon which



THE NEBULA OF ORION—THE VAST SHAPELESS MASS OF GLOWING MATTER THAT GIVES BIRTH TO WORLDS AND WORLD-SYSTEMS

The earth sweeps round the sun in a circle not less than 185 million miles across; and if we could imagine a globe as vast as this, and then imagine a million of these globes rolled into one, this incredible vastness would still be smaller than the nebula of Orion

the history and destiny of stars and planets, and all that planets may bear, ultimately depend. With this demonstration, the case for universal evolution is finally proved.

It will be for subsequent ages to discover the details, to view them in such coherence and sequence that description may yield to explanation, and the course and causes of evolutionary events, in all spheres of existence, be gradually revealed. But we have, at any rate, the advantage of realising this idea of the universe, and of looking upon all things that we may study in this light. We study that which is never the same, yet which is ever the same. Here is the supreme paradox. Every moment in the history of things is unique, yet through all past and future changes, through all that may be possible, the unity and identity of the universe remain. "The more it changes, the more it is the same thing." Cause and effect, infinite and inexorable consequence, bind it in Time, and a thousand subtle bonds of affinity and co-ordination bind it in Space. Though nothing is constant but change, change has its laws. Indeed, what we call the "laws of Nature" are none other than the laws and the conditions of universal evolution. With this understanding we may approach their study and avoid the many pitfalls in which the bones of other wayfarers now lie bleaching.

THE WONDER OF A DROP OF WATER

These pictures show the many forms in which we find water, the universal essential of life. Water can be made into dew, hoar frost, hailstones, snow, mist, rain, and ice, as shown in these pictures, yet it is always water, composed of the same elements, retaining its original weight through all these transformations.

THE EARTH'S FOUNDATIONS

The New Knowledge of the Elements and the Amazing Things that Happen when They Come Together

THE THINGS THE WORLD IS MADE OF

In discussing the making of the earth we have seen that certain substances known as elements enter into the composition of its crust, but so far, we have not considered what we mean by element.

By element we mean an absolutely simple, pure substance that by no known means can be divided into parts with different properties. For instance, if we take the red substance known as mercuric oxide, and grind it into a powder, each grain still remains mercuric oxide; there is no difference between one grain and another. Is mercuric oxide therefore an element? Perhaps!

But we have not yet done our disruptive worst. Let us try the ordeal by fire. Let us heat it. When we do this we find that it is shaken to pieces, and that it divides into a heavy vapour which condenses as the liquid metal mercury and the gas oxygen, which supports combustion. Mercuric oxide, therefore, is not an element; it is a combination of two substances which it is possible to separate. But when we take the two separated substances we may roast them, and freeze them, and electrify them, and do what we will with them—they still remain mercury and oxygen, a liquid metal and a gas, each with certain fixed, definite qualities. We say, therefore, that oxygen and mercury are elements.

Or, to take another instance, we get some tallow and divide it into small pieces. Each piece still remains tallow. We melt it, and it solidifies as tallow. We freeze it, and it thaws as tallow. Is tallow, then, an element? No, we must experiment further. Let us burn the tallow as a candle. Lo! the tallow is torn all to pieces. A black substance, carbon, hidden in its composition, goes off with the oxygen in the air, and forms a gas called carbon dioxide, and a gas in it called hydrogen links arms with the oxygen of the air, and goes off as water. So tallow is certainly not an element, but a very complicated compound, composed of several elements.

Or take water. We can heat water into steam, or freeze it into ice; yet it retains its qualities as water, and gives rise to no substance with other than aqueous characters. And yet water is not an element either, for by passing it over red-hot iron or red-hot carbon, or by passing a galvanic current through it, water can be divided into two gases, oxygen and hydrogen, both of which are quite dry, and neither of which is in the least like the water which the two together form. Even a little piece of potassium laid on water will tear oxygen and hydrogen from it and set the hydrogen on fire. So water, in spite of all first appearances to the contrary, is not an element after all.

Only after a substance has resisted the most violent and ingenious efforts to pull it to pieces do chemists call any substance, whether gas, or solid, or liquid, an element. Even then it is better to be guarded, for chemists have frequently found out that substances which seem simple are really compound, and can be divided into two.

For years and years, for example, caustic potash was considered an element till one day the great chemist Sir Humphry Davy succeeded in shaking it asunder by the electrical process known as electrolysis, and showed that it was really a compound, and that an unknown metal—now known as potassium—could be separated from it. So delighted was Sir Humphry at this discovery that it is said he actually danced with joy. Like most discoveries, this discovery led to more, and Sir Humphry Davy soon broke up some other substances, and extracted from them hitherto unknown elements—sodium, chlorine, magnesium, and

strontium. Since Sir Humphry Davy's day new elements have been constantly discovered, and there are now eighty-one. Some of these were difficult to discover because they were tightly combined in compounds. Some, like the inert gases in the air—neon, xenon, argon, krypton, and helium—escaped notice because they occur in very small amounts, and have no chemical activity. None of these five atmospheric gases combine with other gases; they lead negative, lazy lives, and do nothing whatever to attract attention.

The Little Known Elements, and the Light Given Off by Solid Bodies

About half the elements are well known, and about half are hardly known at all. We have all heard of aluminium, antimony, arsenic, bismuth, calcium, carbon, chlorine, cobalt, copper, gold, hydrogen, iodine, iron, lead, lithium, magnesium, mercury, nickel, nitrogen, oxygen, phosphorus, platinum, potassium, radium, silicon, silver, sodium, sulphur, tin, and zinc. But how many people have heard of columbium or niobium, erbium, gadolinium, indium, lanthanum, neodymium, praseodymium, rhodium, samarium, terbium, thulium, ytterbium, yttrium, zirconium, or europium?

Some of the rare elements have been detected in a most wonderful and interesting way by spectrum analysis. It is well known that the white light of the sun is really a mixture of coloured waves of light, and that the coloured waves can be separated from each other by passing the white light through a prism. All solid bodies, a platinum plate, a steel poker, if heated to what is called white heat, give off similar composite white light that can be analysed into component coloured waves. But it has been found that when any substance is reduced to a state of vapour and rendered incandescent it no longer gives off white light, but certain characteristic coloured rays which can be analysed by a prism, and so distinguished from all other substances. In a rough way the coloured rays can be discerned by the eye, and the coloured lights of pyrotechnic displays are rough illustrations of this principle.

The Analyst who Can Find the 180-Millionth Part of a Grain

The scientific instrument for the analysis of the light of incandescent vapours by means of a prism is known as a "spectroscope," and the actual analysis is known as spectrum analysis.

By means of vaporising substances and analysing their light, the most minute traces of elements may be detected. For instance, one 180 millionth part of a grain of sodium, one six millionth part of a grain of lithium, one millionth part of a grain of strontium and calcium can be detected. In view of the wonderful delicacy of this mode of analysis, it is not strange that it led to the discovery of some of the rarer elements. In 1860 Professor Bunsen was making a spectroscopic examination of the deposit left after the evaporation of the Dürkheim springs in Germany, and he noticed some bright lines he had never seen before. Taking the hint, the professor was led to search for new elements, and succeeded in finding cæsium and rubidium. Once seen and identified, they were found in minute quantities in other springs and minerals. Rubidium, indeed, has been found in coffee, tea, cocoa, beetroot, and tobacco.

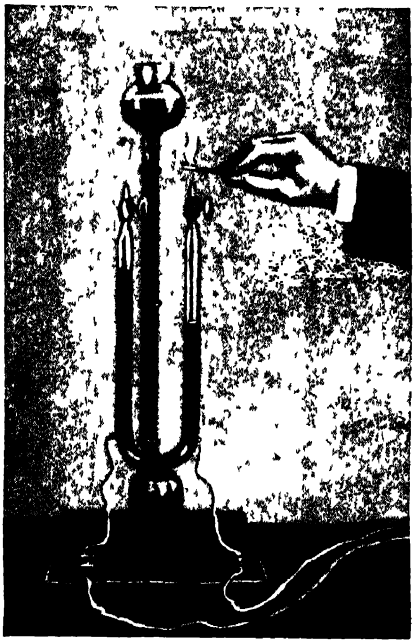
Two years after the discovery of cæsium and rubidium, Sir William Crookes discovered another new element which gives a magnificent bright green line through the spectroscope, which he therefore christened thallium, from *thallus*, meaning a green twig. Two years later two indigo-coloured lines betrayed another element to two German professors, who straightway isolated it and called it indium, because of its indigo light. Finally, in 1875, two violet lines led to the discovery of another new metal which its discoverer named gallium.

The Instrument which Identifies Salt Burning in the Kitchen and Salt Burning in the Sun

The importance of the spectroscope, therefore, in the identification and discovery of elements is undeniable, and a remarkable fact may be mentioned here. However distant incandescent light may be, it can be analysed by the spectroscope, and will give evidence of the element which produced it. We can identify not only the salt burning in a kitchen fire, but the salt burning in the furnace of the sun. A substance burning in the sun 93,000,000 miles away may be detected with as much certainty as if it were in the laboratory, and in this way we have found out the constitution of suns and auroras and nebulæ. In our own sun we have discovered about half the elements known on earth, including iron, carbon, calcium, aluminium, sodium, potassium, magnesium, silicon, hydrogen, zinc, copper, silver, tin, and lead. Gold is not found in the sun, but some of the rare metals are plentiful, and helium was found in the sun before it was found in the earth. In nebulæ an element, nebulium, has been detected which has not been found in earth.

Many of these elements seem very superfluous. We can see some use in carbon, hydrogen, oxygen, nitrogen, and sulphur, since our own bodies, and all the animal life and plant life of the earth, are built up of these elements. We can see some use in iron, since a good many of us ply steel pens and carve with steel knives and shave with steel razors. We can see some use in calcium, since our bones are made of it. We can see some use in sodium when we find it in a salt-cellar. We can see some use in gold. But of what possible use can infinitesimal quantities of samarium, or thulium, or erbium be? The truth is that for many of the rare elements we have not yet found any use, but on the other hand for some, either alone or in combination with other elements, we have found most unexpected uses.

Take, for instance, the well-known incandescent gas-mantle, by the light of which these words are written. It is composed of oxides—compounds with oxygen—of the rare elements thorium and cerium, which are obtained almost exclusively from sand in Brazil, and great care has to be taken to purify the thoria and ceria from other rare elements. Further, the mantle is strengthened by being dipped into a solution of the oxides of aluminium and of the rare substance beryllium, and the name of the manufacturer is written on the burner with a solution of uranium nitrate.



BREAKING UP WATER INTO GASES

Water, which would at first appear to be an element, is not really so, because it can be split up into gases in the manner indicated here. By passing an electric current through it, water is decomposed into two gases—oxygen and hydrogen. In this picture the hydrogen is collecting in the right arm of the tube and the oxygen in the left arm

Professor R. K. Duncan, writing in 1907, says: "In Germany alone over 150,000,000 gas-mantles are manufactured every year, and the total number manufactured the world over staggers belief. To manufacture these German mantles over 330,000 pounds of thorium nitrate are employed, 120,000 of which come from Brazil through the hands of a single firm at Hamburg. Millions of money and thousands of men are employed in the utilisation of a rare mineral which, a few years ago, had nothing but an academic importance."

The rare oxide yttria is used in conjunction with the rare oxide zirconia in the Nernst lamp, the only incandescent electric lamp that burns in air. This lamp gives fifty per cent. greater light per unit of electrical power than the ordinary carbon filament lamp. Millions of these lamps have been sold.

It is interesting to note that cerium and yttrium are plentiful in the sun, and no doubt contribute to its radiancy.

In the Welsbach lamp the filament is made of the very rare element osmium. Osmium is a very refractory substance, more than twenty-two times as heavy as water, resistant to all acids, and fusible only in the electric furnace. The lamp gives a beautiful and economical light.

Another rare metal, tantalum, is used as filament in other electric light lamps. Tantalum is an extremely rare metal, found in very few localities. Like osmium, it is very resistant and refractory. In a slightly alloyed specimen it was found impossible to pierce with a diamond drill a sheet one-twenty-fifth of an inch thick, even though the drill rotated for three whole days at a rate of 5,000 times to the minute. Even when quite pure it is as hard as the hardest steel; it does not rust; and it can be melted only at 2,300 degrees centigrade. It can be drawn out into such fine wire that though twenty inches of wire are required for each lamp, a single pound of osmium is enough for 20,000 lamps.

The rare metals tungsten, helium, and molybdenum have also been used for electric light filaments, and the filament of the well-known Osram lamp is made of an alloy of osmium and tungsten.

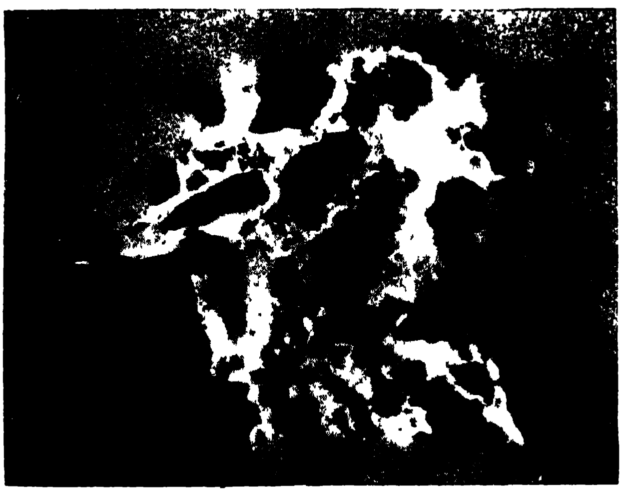
These rare elements, therefore, have been put to noble use—have been employed to transform darkness into light. It is strange to think that these refractory metals from the bowels of the earth should be used to light it, and should become vicars of the sun.

Some of the rarer elements are also found useful in the preparation of alloys. Thus, steel can be quite altered in its properties by the addition of small quantities of vanadium, tungsten, chromium, molyb-

denum, nickel, or titanium. Even the sluggish, inert gases of the air may at least perform æsthetic functions, since it seems probable that incandescent krypton produces the green light of the aurora borealis.

He would be a rash man indeed who would dare to assert that any of the elements are useless in the economy of man and Nature, or that even now all the most wonderful metals have been found. Out of the elements common and rare are woven all the compound bodies of the world—the flesh of animals, the tissues of vegetables, the granite of the mountains, the water of the seas, the ooze of the sea-bottom.

One of the most essential properties of matter is its weight. It is weight that holds the world together; it is weight that makes the tides; it is weight that holds the moon to the earth; it is weight that holds the earth to the sun, and keeps the stars in their courses. If we take a certain weight of an element we can melt it or vaporise it or freeze it, we can change its colour and its shape and its consistency, but we cannot change its weight. A pound of water remains a pound of water, though we freeze it into ice or vaporise it into gas. Chemists, accordingly, soon began to examine the weight of elements and compounds.


A PIECE OF PITCHBLENDE, THE SOURCE OF RADIUM

They found that some are light, like hydrogen, and some heavy, like lead, but they found out a more interesting fact still—that the elements always combine with each other in weights, either exactly proportionate to their relative weights or in some exact multiple of these. Thus, oxygen is sixteen times the weight of hydrogen; and water, a compound of these two elements, contains two parts by weight of hydrogen to sixteen parts by weight of oxygen. Hydrogen peroxide, another compound of these two elements, contains two parts of weight of hydrogen to thirty-two parts by weight of oxygen. Again, the weight of carbon is to the weight of oxygen as twelve to sixteen —or three to four—and one of their compounds, carbon monoxide, contains twelve parts by weight of carbon to sixteen parts by weight of oxygen, while their other compound, carbon dioxide, contains twelve parts by weight of carbon to thirty-two parts by weight of oxygen.

Why should this be? Why should elements have these exact combining weights? Why should not hydrogen and oxygen equally well combine in irregular amounts by weight?

John Dalton answered this question by propounding the atomic theory of elements. He said that the elements could combine only in the proportions of their relative weights, or in some multiple of these, because all the elements were divided into particles that had certain definite weights, and could not be sub-divided. Assuming this—assuming that compounds must unite particle by particle—it necessarily follows that the relative weights of the particles must determine the relative weights of the elements in any compound. The essence of the theory is that the ultimate particles of matter are of definite weight and indivisible, and that each element has its own particular particles or atoms, with a particular weight or atomic weight.

Suppose one elemental atom weighs one grain, and another twelve grains. Then they may unite in proportions one and twelve by weight, or two and twelve, or one and twenty-four, or two and twenty-four, or four and twelve, or in any proportions that are multiples of their atomic weights, but they cannot unite in such proportions as one and seven, since that would obviously involve the sub-division of a twelve-grain atom into seven and five. The very fact that such irregularities in the combining weights of elements never occur seems to prove that their ultimate particles are really indivisible, and of definite weight. The weight of the atom of the element fixes the properties of the element.

The idea that matter is built up of ultimate indivisible particles is a very old one, having been first formulated by the

WEIGHING A GRAIN IN A MILLION PARTS

THE MARVELLOUS SCALES WHICH WILL WEIGH THE MILLIONTH OF A GRAMME OF RADIUM

A GUILLOTINE AT THE RADIUM INSTITUTE WHICH WILL CUT A 25,000TH PART OF AN INCH

By means of vapourising matter and analysing its light, the most minute traces of an element may be detected. A millionth part of a grain of calcium can be traced, and even one 180 millionth part of a grain of sodium. The same measurement of infinitely small portions is achieved at the Radium Institute in London, where these photographs were taken.

Greek philosopher Democritus, and we find the great Sir Isaac Newton propounding it in no uncertain words. " It seems probable to me," he writes, " that God in the beginning formed matter in solid masses, hard, impenetrable, movable particles of such sizes and figures, and with such other properties, and in such proportion, as most conduced to the end for which He formed them; and that these primitivè particles, being solids, are incomparably harder than any porous bodies compounded by them, even so very hard as never to wear or to break in pieces, no ordinary power being able to divide what God Himself made one in the first creation."

Dalton, of course, was not the author of the atomic theory, but he applied it to explain the facts of chemical combination; and though modern science begins to doubt the indivisibility of the atom, it will never cease to find the theory a most useful working hypothesis.

Though the elements have each individual weights and individual characters, yet some of them have resemblances to each other; and a German chemist, J. W. Döbereiner, showed that some of them could be arranged in threes or triads, so that each triad should contain elements noticeably like each other.

MENDELÉEF, WHO FORETOLD UNKNOWN ELEMENTS WITH AMAZING ACCURACY

Professor Mendeléef, the great Russian chemist, was able by his investigation of the elements to predict not only that unknown elements would be found, but that they would possess particular properties. In time the elements were discovered, answering almost exactly to his predictions.

But much more remarkable groupings of the elements were yet to be found. Professor Mendeléef and other authorities have shown that if the elements, beginning with lithium, be arranged in series according to their atomic weight, every element tends to repeat, in increasing or decreasing degree, the properties of any other element eight removed from it. Thus the first and the eighth and the sixteenth have remarkable similarities; so have the third, the tenth, and the seventeenth; so have the seventh, the fourteenth, the twenty-first; and so on. If we simply arrange the elements serially, according to their atomic weights, in horizontal lines of seven, we obtain perpendicular rows of related elements.

Each of the groups in such a table contains members with strong family resemblances to each other; and as we run up and down them, the particular family features either progressively wax or progressively wane; and if we know the physical and chemical characters of any one, we can tell pretty exactly the physical and chemical characters of its neighbours.

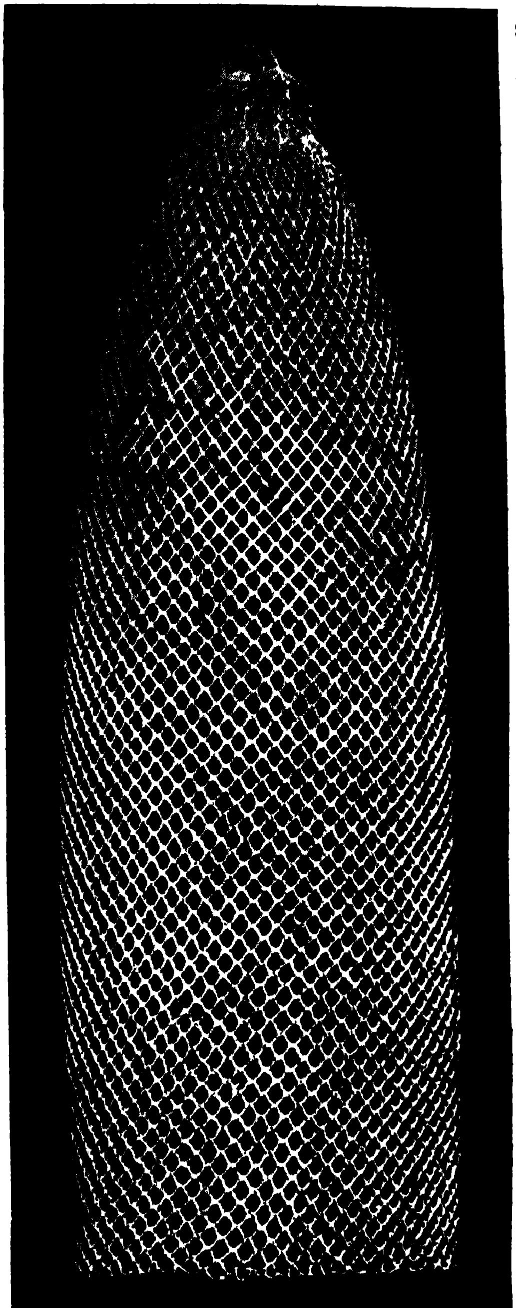
As Professor Duncan well says: " The periodic law of the atoms is God's alphabet of the universe. By means of it only can we ever hope to spell out the history of the future of creation. It lies before us, lacking only the master-word—the open, sesame—to creation; and, who knows, to the Creator, too ? "

To illustrate the efficacy of the law we need point only to its prophetic value in the hands of Mendeléeff. When Mendeléeff first made his table, scandium, gallium, and germanium were unknown, and in order to bring his grouping right Mendeléeff had to put blank spaces where these elements are now placed. But he was sure that elements there must be to fill these blanks; and from the situation of the blanks in the scheme he was able to predict almost the precise properties the missing elements must possess. In time the elements were found " out of the night of the unknown, one after another came to meet him. One from the the hills of Scandinavia, another from the Pyrenees of France, and a third from the mines of Germany," and they were found to answer almost exactly to his predictions.

Surely a law with such amazing prophetic power—able to foretell the properties of an element unknown by man since the beginning of the world—must be based on a firm foundation.

Let us now look for a moment at molecules. Atoms seldom, even in simple gases, remain single; they always tend to join and form complexes known as molecules. The basis of all compounds—and there are hundreds and thousands of compounds in the world—is the molecule formed by the junction of atoms. In most inorganic compounds the atoms that make the molecule, and by their conjunction produce all the

properties of the compounds, are usually only two or three. Thus, water consists of two atoms of hydrogen and one atom of oxygen; sulphuric acid consists of two atoms of hydrogen, one of sulphur, and four of oxygen; and carbon monoxide consists of one atom of carbon and one of oxygen. On the other hand, the molecules of organic substances, and of the so-called carbon compounds, are often composed of a multitude of atoms. Thus, the molecule of blood-albumin or serum-albumin has been analysed into 450 atoms of carbon, 720 atoms of hydrogen, 116 atoms of nitrogen, 140 atoms of oxygen, and 76 atoms of sulphur; while the chemical composition of nuclein is still more complicated, nuclein being a complex albuminoid substance containing phosphorus and iron in organic combination. In many cases the atoms in the carbon compounds are built together in bits, so to say, and their architecture is indicated by names such as *tri-phenyl-triamido-di-phenyl-tolyl-carbinol*, and *hexa-phenyl-iso-propyl-methyl-ketone-carboxylic acid*. Chemistry consists mainly in a knowledge of the different affinities of atoms, and of ways in which molecules can be broken down and built up, and the science of modern synthetic chemistry has succeeded in building up some thousands of interesting compounds that are quite unknown in nature.



A RARE ELEMENT THAT HAS LEAPT INTO UNIVERSAL USE

It is often asked what purpose the rare and little-known elements can serve, and it is true that for many elements no use has yet been found. But it equally true that an element known only to scientists a few years ago as a thing of academic interest has now become the basis of an enormous industry. Out of some of the rarest elements are made the hundreds of millions of incandescent gas-mantles now used throughout the world.

It is a curious thing that the social proclivities or combining tendencies of atoms vary immensely, some—such as argon and fluorine — being very averse to combination, and others—such as carbon, oxygen, nitrogen, and hydrogen — being willing to combine in an infinite variety of ways. The force of affinity also varies in a very interesting way. Potassium is so fond of oxygen that if a little piece of potassium be laid on the surface of water it will rush about, tearing up the molecules to obtain oxygen, so fervently that it sets fire to the hydrogen. Hæmoglobin, again, seizes oxygen readily, but does not retain it very firmly, otherwise we should all be in a sorry, cyanosed condition. Fluorine, again, will not have oxygen at all, but rushes to hydrogen with explosive violence.

Even more interesting and wonderful than chemical affinity itself are the results produced by the combination. The two gases oxygen and hydrogen join, and behold we have the wonderful liquid water. The metal gold and the corrosive vapour chlorine join together, and lo! we have a clear fluid. The carbon of a diamond and the oxygen of the air join, and lo! we have a suffocating gas. The gases oxygen, nitrogen, and hydrogen join with a little carbon and sulphur, and form a seed that grows to a man. In the affinity of elements lies all the mystery of material form.

LIFE BUILT UP BEFORE OUR EYES

This astonishing photograph shows, 40,000 times bigger than they really are, a colony of living cells, each one of which is reproducing itself by dividing into two, which divide into four. All cells of living creatures are derived by development from a single cell. These cells, photographed by Mr. J. J. Ward, represent the lowest kinds of green plants—the organisms which often produce the slipperiness of rocks in moist places. The principle of reproduction is similar, however, in most forms of life.

LIFE REPRODUCES ITSELF

The Marvellous Processes by which Life Divides and Multiplies and Builds up Every Living Race

THE SUPREME MIRACLE OF THE WORLD

LIFE persists and excels itself, but all living individuals die. All individuals being mortal, the maintenance and the destiny of all living species depends upon the capacity of the individual, before it dies, to reproduce itself, or leave some living remnant or minute epitome of itself from which will be again produced a creature to replace that which is gone.

It has been suggested that, on other worlds, life might embody itself in permanent continuous forms, and that, for instance, the markings on Mars might be due to one persistent, straggling, undying body of life. But on the earth, at any rate, and for reasons which we can begin to divine, the continuance of life is in a tissue of births and deaths.

Individuals may persist for amazing periods. We may find giant tortoises which are centuries old, and trees which are thousands of years old, but we find that they die at last, and we have only to examine them in order to find that they were constructed—tree, day-fly, take what creature we will, long-lived or short-lived—not wholly, if even primarily, for themselves, but for reproduction, for parenthood, and the future.

The modes of reproduction are many, and in the vegetable world especially we find such cases as that of the strawberry, with its runners; the begonia, which can be reproduced from a portion of a leaf; and other exceptions to the rule. But they are merely of curious interest, and the rule to which they are the exceptions is universal, applying to the strawberry and the begonia as well as to all other living forms. It is that the individual animal or plant yields a portion of itself, which is never more and never less than a single cell, and from that cell the new individual is formed. Every living individual is either, as some are, a single cell from first to last, or else, as all the higher forms are, a multitude of cells developed from a single cell. Thus even the many-celled animals and plants, including ourselves, are single-celled in the first period of their life. Here is a problem, evidently, for we have to explain how the single cell becomes an oak or an elephant or a man, and that is the great vital problem called development.

But we shall never solve the questions of development unless we begin at the beginning, and there is enough here to engage us for many a long day. We must not attempt too much at once, for we are dealing with the most complicated and difficult subjects of all imaginable inquiry. Even the human brain is simple compared with the problems of a microscopic cell which develops into a man, brain and all. Therefore, we must definitely leave development out of the question at present, as writers in the past have too often declined to do, and we must try to find the facts of these cells from which new individuals grow, and which are in themselves the new individuals at the earliest stage of all the many stages between their begetting and their death.

There is plenty of material to study, for birth and death are on all hands. Indeed, the first general fact of reproduction is its extent and its insistence. Over-production is the keynote, the ruling principle, of the living world. It seems to involve the most unheard-of waste, yet it is the definite and constant rule, and we have good reason for believing, from all manner of other evidence, that economy of means, and waste of nothing, is no less a principle of life. The truth is that this apparently insane and purposeless excess of reproduction, which leads living beings to form thousands and millions of cells, sometimes millions a year, each one proposing to grow up into a new individual, and not one in millions succeeding, is not really wasteful if we look at life as a whole. The countless eggs of the fish

which never reach maturity are consumed by other fishes and inhabitants of the sea, and serve their lives. The immature members of almost any species, animal or vegetable, are the staple diet which maintains the life of other species. As regards any particular species, the lavish abundance of its reproduction seems utterly wasteful, but as regards the sum total of life there is in the long run no waste. The point is well worth making, for the waste involved in reproduction is one of the standing themes of amateur comment, and has been constantly described without the further observation which shows that the waste is more apparent than real.

A Microbe that Might Grow into Thousands of Tons of Microbes in One Day

The capacity of reproduction, if only there be nothing to interfere, and if food for the new cells to live and develop be available, is beyond all bounds. A single microbe, with a fair field and no opposition, could become sixteen millions in twenty-four hours. Not, of course, that the necessary supply of food and oxygen, and so forth, could ever quite satisfy such a figure, but the observed rate of reproduction would correspond to such a figure if circumstances permitted. The microbe of cholera, which is capable of doubling itself every twenty minutes, might in the course of a single day become 5,000,000,000,000,000,000,000 microbes, with a weight estimated at 7366 tons. One microbe has actually been observed to become 80,000 in twenty-four hours, and 20,000 injected into a rabbit have been found to reach the number of twelve thousand millions in a day.

And if we consider the rabbit itself in Australia, or the rat, or some new weed introduced into American streams, or any other case where the potentialities of reproduction get a chance to show themselves, we find that a single pair of individuals will soon people a continent, or a single seed become the parent of a forest.

How Life Overruns the Land and Crams the Sea with Ever-increasing Speed

Wherever reproduction gets its head, life overruns the land, or crams the sea, with inevitable and ever-increasing speed, for its method is that of geometrical progression—1-2-4-8-16-32 . . . and millions in no time. It is only because there are so many living species, animal and vegetable, and such long-standing balance of numbers, on the whole, between them, that we do not realise the full measure of the reproductive pace, except in novel circumstances, where man's interference, or some other unusual factor, has altered the balance of nature, and given some species or other an open field for development.

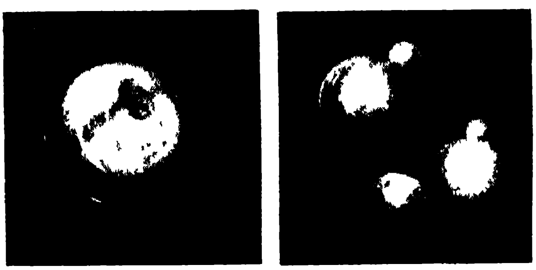
This tendency of reproduction definitely involves over-production. The normal case, for any species, is that more, vastly more, new individuals are produced than can possibly find room for their development. Accordingly, they die, as a rule to form the food of some other species; or, at the worst, to serve the cycle of life by the decomposition of their dead bodies. There is no ultimate waste, we therefore see, and there is much possible gain, of a kind which has only lately been guessed. For this over-production is a cardinal part of the foundations of Darwin's theory that organic evolution is due to natural selection. If there be vacancies in your service for all the candidates, the duffers and the lazy will all get places, and your entrance examination is a farce. Just so, if there be food and room for all the young of a species, none will be rejected, and there can be none of that process of natural rejection, which is the more accurate name for natural selection.

The Amazing Cell of Life from Which Every Living Creature Comes

This over-productivity, normal throughout the living world, and without an exception, until we reach the case of civilised and very recent man, is therefore to be permanently kept in mind as an essential factor of one of the great moulding forces of the living world.

Let us now look, if we can, at the details of the process which has such stupendous consequences and possibilities. It is an all-important step to have learnt, thanks to the illustrious Harvey—still more celebrated for his discovery of the circulation of the blood—that, as he said, every living thing is from an egg—*omne vivum ex ovo*. We can now, thanks to his beginning, make the statement more precise, and say that every living thing is derived from a cell. We concentrate therefore upon these cells, and ask their origin and history, and their relation to the individual which bears them, and dies, and leaves them as its legacy to the future. We shall find very great contrasts between the simplest and most complex forms of the process of reproduction, but we shall find quite simple principles throughout. Above all, we shall find that the study of reproduction teaches us far more about the living cell, its structure and its nature, than we could ever learn about it by the study of cells which are not engaged in this extraordinary process.

Naturally, it is the one-celled creatures that provide us with the simplest case, and the simplest of them are indeed too simple to teach us much. If we observe a microbe, a simple-celled vegetable creature, which has no nucleus, and almost no visible structure whatever, we find that it divides by what is called fission, or splitting. It really seems to live for this purpose, and we have seen that in twenty minutes or half an hour, under favourable conditions, one generation passes and is replaced by another. The little cell shows a sort of constriction at opposite sides or ends—as if an invisible string were being tightly drawn round it—and splits into two. It seems to be just a matter of convenience, for purposes of getting food and oxygen, that when the cell has reached its full size, and still wants to increase its life, it should split into two rather than grow inconveniently larger. As to the details of the process, and the manner in which the constriction is brought about, we cannot say; but the students of physical forces and processes, such as the passage of fluids and solutions through membranes, are beginning to suggest that this splitting of simple cells may be more or less explained in terms of what we observe apart altogether from the action of life.



TWO WAYS IN WHICH CELLS REPRODUCE THEMSELVES

The first of these pictures shows a cell about to divide by splitting as if an invisible string were being drawn tightly round it. The second shows yeast cells reproducing themselves by buddi the cells of simple plants sometimes do.

Reproduction of this kind is so utterly remote from what we observe in the case of all but the lowliest forms of animals and plants, that we almost feel as if nothing could be learnt from it. That, however, is not the fact. We here see that what we call the body in the case of higher forms does not exist. These creatures are all *race*, so to say, and individuals worth recognising, who have bodies of their own that die with them, do not exist. If we use Weismann's term of germ-plasm, we see that the microbes and similar forms are *all* germ-plasm—there is no body, and therefore no body-plasm with which to contrast the germ-plasm, as Weismann has so wisely taught us to do in the case of higher forms.

The yeast-plant offers us a good and familiar illustration of a mode of reproduction which is not quite so simple as fission, but which is only removed from that simplicity by a step. The yeast-plant is a round cell, which grows to its full size, and then, instead of splitting into two, forms a sort of bud, which at length becomes detached and constitutes a new individual. Sometimes we may see a series of such buds, of diminishing size, more or less attached to each other, and in a little while they will each be free and independent. This reproductive process is called reproduction by gemmation, or budding. It is a stage higher than fission, for in this case the parent can be identified, and survives the reproductive process; but, all the same, we see that there is not very much difference between the cell which splits into two and the cell which, instead, buds off somewhat less than one-half of itself. In such a case as the yeast-cell, or the other simple forms of life which reproduce by budding, there is no nucleus, and therefore in this case there arise none of the problems which the presence of a nucleus involves.

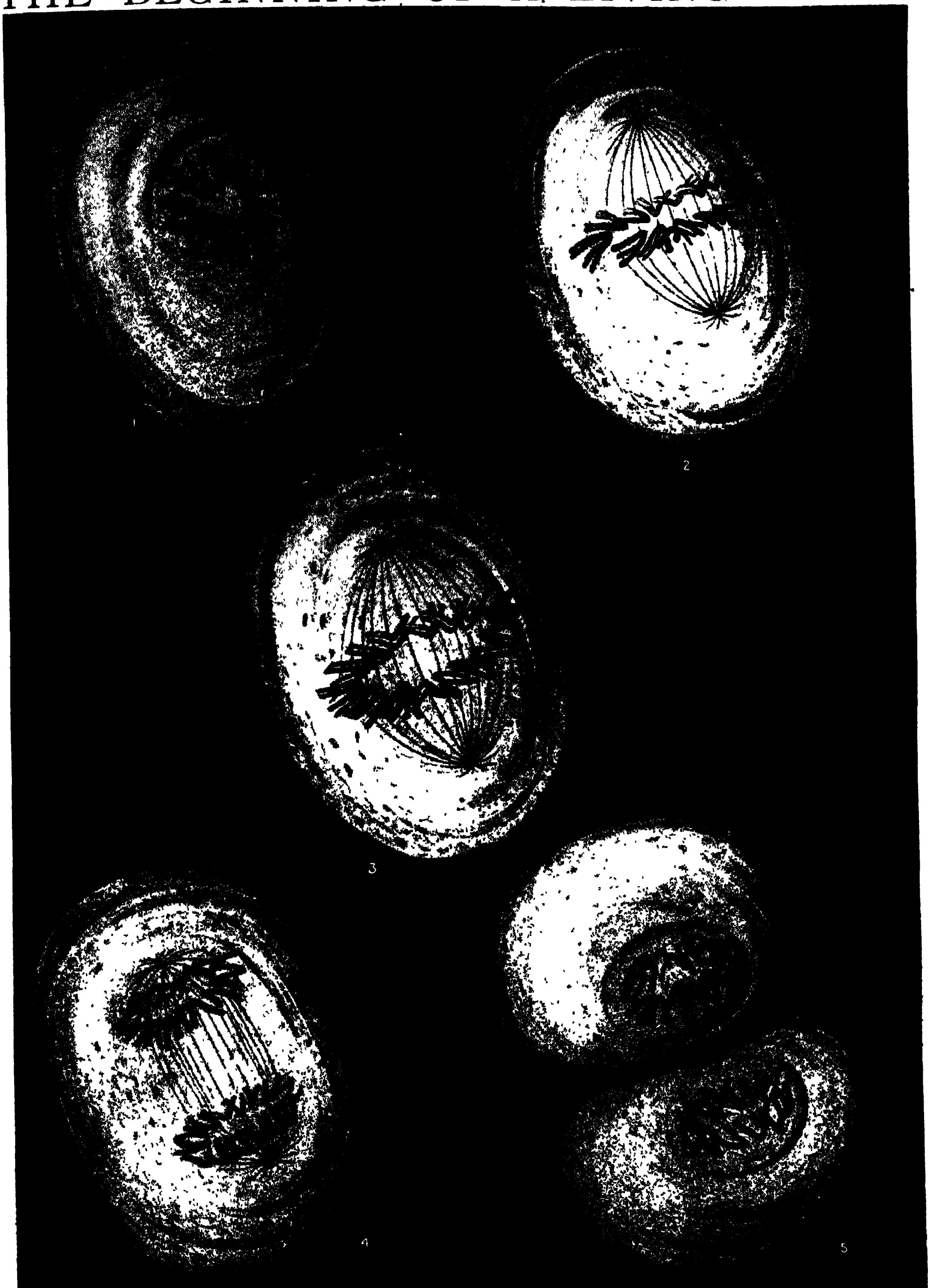
The very astonishing fact has been observed that in some species which reproduce themselves in the simplest fashion, and in which there is no such thing as sex, individuals can nevertheless be observed to fuse and become one—just the opposite process to that we have been describing. This process is called conjugation, and in these lowly forms we observe for the first time a phenomenon of life which is of scarcely less importance than cell-division, and the full meaning of which we are still unable to discover. That cells should grow and divide, either cells that are complete individuals in themselves, or cells forming part of a growing body—this we can understand; but it is another matter to explain the exact opposite of this process, two separate cells becoming one.

This looks like a reversal of the stream of life and as if the tendency of living things were being defied. We shall learn, however, that cell-division is served by cell-union, for wherever there is sex, cell-union or conjugation involves the formation of cells which are destined to divide, and change as they divide and multiply, until we see before us the full-formed and infinitely complex body of a horse, an oak, or a man. There is thus some subtle fact of the living cell and its processes which expresses itself in a kind of balance between

THE KEY TO ALL THE PROBLEMS OF LIFE

The living cell, represented in these pages as the fullest powers of the microscope reveal it to us, holds the key to problems which have baffled men through all the ages. So small that ten millions of them could come into a single square inch, a single one of these cells has in it all the potentiality of life—of an oak, or a lion, or a Shakespeare. Every living thing is made up of cells similar to this, linked together into a continuous wall of tissue On the right-hand page is an attempt to represent the very beginning of a living thing. The large cell on this page may be called the mother cell. The right-hand page shows how from this cell proceed daughter cells. In the first cell the nucleus is in its normal globular form, and its vital substance is arranged in loops, which are called chromosomes. The two black specks on the outer edge of the nucleus are called centrosomes, and here they are seen separating to opposite poles. In the

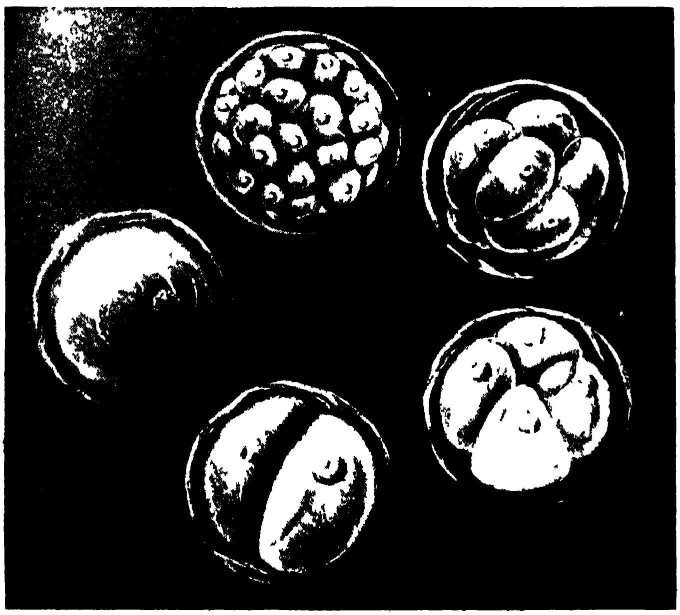
THE BEGINNING OF A LIVING THING



second cell the centrosomes have formed two opposing spheres of attraction, with fibres, in spindle form, connecting them. Round these fibres the chromosomes arrange themselves, and an amazing thing now develops. In some mysterious way each chromosome is split lengthwise, with the result shown in the third cell, and the two separate themselves to the opposite poles, though still holding to the filament attached to the centrosomes. The stage shown in the fourth cell is thus reached, and now occurs the supreme miracle of the living world, upon which life and all mankind depend. The fibres break in two, and each set of chromosomes becomes a separate nucleus. The cell divides, and in place of the mother cell there remain two daughter cells, each in time to become a mother cell. So these two multiply themselves, and so, from the beginning of living things till now, has all life been sustained.

cell-division on the one hand and cell-union on the other. This we see in its completeness if we contemplate the sequence of events from generation to generation, in any of the higher forms of life. Two cells unite, as we shall see, and form one. This divides and forms billions in the body of the new individual. Of these billions some are such that if one of them unites with a similar cell from another individual, another new individual will be formed. The sequence of generations, the making, growth, and destiny of successive bodies, is therefore a rhythm of alternating cell-union and cell-division. This we observe and describe, but it is not yet awhile that we shall explain it.

Allusion has been made to a fact which is closely associated with reproduction and is thought to be an essential part of it, the fact of sex. We shall make no real progress with our subject unless we rid ourselves from the first of this almost universal and certainly very excusable misconception. Observe that it was possible to describe unquestionable reproduction in the case of many efficient and successful and important races of living beings, without any allusion to sex at all. Not only those such as we have mentioned, but many creatures such as the amœba, which has a nucleus, and goes through a vastly more complicated reproductive process—exactly the same as that gone through by the cells of all the higher and highest forms of life—are totally without sex.



HOW THE CELLS OF LIFE MULTIPLY

These pictures show the multiplication of the cells in a crab, and they are typical of all living things. On the left is seen a single cell, which divides into two, which become four. So cell division goes on indefinitely—cells join together in a million ways, and a living creature is in the world.

We may say, if we like, that all the individuals of these species are of one sex, in which case the sex must evidently be female; and certainly the female sex may thus claim greater antiquity than the male. But, at any rate, sex, and the relations of sex, and the different forms of the two sexes, their different functions, and all that this implies, alike for individual life and for reproduction itself—all this is totally absent in many species, and is to be looked upon as unquestionably a later development of evolution, a new complication, not essential, which has been introduced, for some reason or other still highly obscure, into the process of reproduction.

Thus what we have been describing hitherto all comes under the heading of *asexual*—that is, not sexual—reproduction, and we shall not appreciate its importance unless we glance for a moment at far higher levels of evolution, and observe the facts of reproduction in certain species, as, for instance, many insects, where sex is a well-established and important fact. These creatures, of course, illustrate sexual reproduction, but the remarkable fact is found that, notwithstanding the existence of two sexes, the females alone will sometimes reproduce. This phenomenon is known as parthenogenesis, or virgin-birth, and a notable case of it is furnished by the social bees. When both sexes are concerned in reproduction, the offspring may develop, according to the food they receive, either into queens or into workers, which are stunted and imperfectly-developed females. But where the females alone are concerned—that is to say, when the eggs of the queen have wholly been derived from her alone, we find that these unfertilised eggs—to use a delusive old phrase—develop into males, or drones. Clearly, then, sexual and asexual reproduction both have their place in the economy of the beehive, and though both sexes exist, the females retain the primitive power of living creatures before sex was evolved at all, and can

become mothers without any contribution from the males. This justifies the view that, as has been said, " Life is female," and it is a clear and conclusive refutation of the idea that reproduction is an act of sex, and that the two are always necessarily allied.

We cannot, however, discuss sex or sexual reproduction without first studying the case of asexual reproduction in creatures which have nuclei in their cells; or rather, which consist of nucleated cells. This is necessary because we shall find that the nuclei of what are called germ-cells play the essential part in the process of sexual reproduction, and we shall be in some degree prepared for the remarkable behaviour of the nuclei in these cases if we find, first, how a nucleus behaves in a dividing and reproducing cell, apart from sex at all.

The amœba will serve as an illustration. A dividing white cell from a drop of our own blood would really do as well, if we were sure not to be confused by the vast difference between the cell which is a complete individual in itself, and the cell which is an infinitesimal unit in a body such as ours. Nevertheless, we do well to learn that the process is really the same in the two cases, for it will prepare us to understand that the act of reproduction, whereby the amœba divides into two separate individuals, is in essentials the very same as those numerous acts of cell-division by which a body is formed and develops and completes itself.

What We Can See of the Growth of Life Under the Microscope

Let us, then, see what happens to and in the amœba. When it is full grown it divides. If we observed it under a high-power microscope, we find that the process depends upon the nucleus, and that the division of the cell as a whole is simply the last step, after a series of other steps have been taken by the nucleus. Not until they are completed, and have resulted in two complete nuclei, lying inside the cell, one rather towards one side and the other rather towards the other side, does the cell as a whole divide. The general cell-plasm, or cytoplasm, plays an entirely subordinate part. It initiates nothing, and does nothing until the very end, when it simply parts in two, so as to enclose each of the two young nuclei with a cell-plasm of its own. We must regard the cytoplasm as indeed only a subordinate and non-essential part of the amœba, or of any cell which has a nucleus at all. The cytoplasm protects the nucleus, contains, and even obtains, nourishment for the nucleus, and doubtless, receives the waste products of the life of the nucleus; but the nucleus *is* the essential cell, just as the brain is the essential man; and cell-division and reproduction in all cells, animal or vegetable, that have nuclei is nuclear division.

The Marvellous System which Must Have Its Home in the Nucleus

It might be that nuclear division was much after the fashion of the division of an entire cell, such as a microbe—that the nucleus simply became constricted and then divided into two by a sort of splitting, and that this was followed by the division of the cell-body as a whole. On the contrary, we find that the nuclear division depends upon a long series of changes inside the substance of the nucleus. Their object, it would appear, is to ensure, as far as possible, that every tiniest part of the nucleus, which must have many parts, each with its own uses and functions, shall be separately and scrupulously divided, so that each of the daughter nuclei and each new cell shall have a due share of every part of the parent.

We know that, with important qualifications, species indefinitely maintain the specific characters of their type. This could only be if, in the course of the cell-divisions upon which the history and existence of each species depends, there was this just and exact subdivision of the nucleus in minute detail, so that a little portion of everything went into every member of the next generation. If we think of the case of a one-celled animal, such as the amœba, and take the hypothetical case described above, we shall see that this must be so, even to far minuter details than the difference between locomotion and sensation. The tiny details of locomotion and sensation are similar in amœbæ generally; each of these details must somehow be represented in the nucleus, and duly shared between its daughter nuclei when it divides, if the daughter nuclei are to become the nuclei of amœbæ which, in a thousand particulars of structure and function, display the ancestral characteristics of their species.

The Mysterious Breaking-up that Occurs Inside the Nucleus

We know that a cell-nucleus, wherever we find it, has a definite structure. It may be the nucleus of a human blood-cell, or the nucleus of a cell which will develop into a human being, or the nucleus of an amœba, or of a cell of an oak. In every case it has just the essential structure which we see in the case of the amœba, having a complicated network which stains well when dyes are applied to the cell, and is therefore

called the chromatin. If we watch the amœba when it reaches the period which demands cell-division, we find that the nuclear network begins deliberately to break up and resolves itself into a number of lengths or pieces, each quite separate from the rest. The number of these pieces, in any species, is constant, and is maintained in every cell of any part of any individual of the species. The amœba is never more than single-celled; but if we looked at a mouse or a lily, we should find that the number of the chromosomes in any dividing cell of any mouse, and in the cell from which any mouse is made, is always the same. Sixteen is a very common number, but in some species it is eight, in some twelve, and so on; but the rule is that the number, whatever it be, is always even. This is not a matter of chance, nor a trifling curiosity, as we shall learn when we come to study sex and its consequences.

The next stage of reproduction involves much movement inside the nucleus, and so do future stages. This entire process has therefore been given the name of karyokinesis, which simply means nuclear movement, and it is in karyokinesis that the ultimate problems of development and heredity are now slowly beginning to find their solution, or the key to their solution.

The Amazing Processes of Breaking Down and Building Up Inside a Living Speck

The pieces into which the chromatin network of the dividing nucleus breaks up are called chromosomes, or colour bodies, and the next fact we observe about them is that, no sooner are they formed, than they proceed, each and all, to split lengthwise, so that the sixteen chromosomes—if that was the number—are now thirty-two. Meanwhile all the chromosomes have contrived to arrange themselves in regular fashion in the very centre of the nucleus, while at two opposite sides of the nucleus we find a small round object from which proceed what look like a number of fine threads, moving toward the centre where the splitting chromosomes are arranged in a sort of plate. The figure thus made is like a spindle, as the accompanying series of pictures show. When the chromosomes are split, one half of each seems to be drawn towards one pole of the spindle, and the remaining half to the other. At the end of this stage, we therefore have sixteen halves of the original chromosomes at one side of what was the nucleus, and sixteen at the other. Little more is required for each set of sixteen to settle down at its own pole, for the separate sixteen, in each case, to fuse together, and form a nuclear network once more, and now, in a little while we have two nuclei in the cell, the cell-body divides between them, and the process of reproduction is completed.

The Exact Reproduction of the Cell in Two Perfect Halves

We must particularly observe that this whole process has been orderly and precise, and that its object has clearly been to obtain a just and complete subdivision of the structure of the original nucleus, so that its daughter nuclei may each have half of everything that was in their parent. And we observe how the splitting of the chromosomes and the careful withdrawal of the split halves, each to its own side, ensures that, in each of the daughter nuclei, the number of chromosomes shall be the same as in the parent. Thus, from generation to generation, the particular number characteristic of the species is maintained. The sixteen in each daughter nucleus fuse and form a network. But when the new cell divides, in its turn, its nuclear network will break up into sixteen chromosomes, as its parents did; and each of these sixteen will split—and so the process will be indefinitely repeated.

No further problem, in the matter of the number of the chromosomes, arises in the case of such an organism as the amœba, or any other asexual species.

It is plain, however, that a difficulty must arise if we consider a sexual species where the new generation is formed by the cell-union of a cell from an individual of one sex, and a cell from an individual of the other. Each of these cells will, of course, essentially be a nucleus, the chromatin of which consists of, say, sixteen chromosomes. If, now, these two nuclei fuse, will not the number of chromosomes in the new nucleus, and, therefore, in the new generation, and in every cell of the new individual, be not sixteen but thirty-two? It would naturally seem to be so.

The Centre Body of the Cell which Initiates the Wonderful Changes

We shall later see how, in the evolution of sex, life has provided a remarkable arrangement, only lately understood, whereby this apparently inevitable doubling of the number of chromosomes in successive generations is avoided.

The process of karyokinesis has been studied with minute care in a vast number of species, and different observers vary in their description of the minuter details.

Certainly, also, such details vary in different species. Great discussion is maintained on this topic, but it is of little importance whether one observer describes ten stages in karyokinesis and another twelve. There is no question as to the essential fact, which is the formation, and splitting, and due allotment of the chromosomes. But there is one other fact which must be mentioned in connection with this important process.

In a typical cell, close to the nucleus, but not in it, we find a small object, quite distinct, forming part neither of the nucleus nor of the cytoplasm, which is called the centrosome. We shall not make headway with this subject until the unfortunate clash between "centrosome" and "chromosome" has been overcome by the memory. The centrosome, though it is not part of the nucleus, plays an essential part in the process of cell-division, and itself scrupulously divides into two parts. Further, it is the centrosome that starts the process of cell-division and karyokinesis of the cell. If we watch the cell, we find that, before the nucleus begins to show changes, the centrosome does so, and it is clear that the centrosome stimulates and initiates the nuclear changes.

The Problem of Karyokinesis Which Lies at the Heart of Life

This wonderful instrument of life, which is clearly shown in the pictures appearing on other pages of this chapter, is thus most clearly entitled to its name as the central body of the cell. The centrosome divides, its halves part, and these two halves are the two directing and essential bodies from which proceed the threads that control the splitting chromosomes, and draw the split portions to their appointed places.

Karyokinesis, or nuclear division, lies at the very heart of the problems of life. Whether it be an amœba dividing into two amœbæ, or a germ-cell uniting with another germ-cell, to form a new single cell, which in its turn divides to form the billions of cells in the body of a new individual, karyokinesis is the essential and central fact of all these processes. If it is remarkable in the amœba, or in the cells of growing skin, or the dividing and multiplying cells of the skin at the edge of a healing wound, it is much more remarkable when studied in the light of sexual reproduction, with its new complications and consequences, as we shall see. But even altogether apart from its meaning and purpose, the mere series of facts is amazing. The detail is so precise and complicated, the order and programme so clearly laid down, the result so exact, and the whole process so unfailing—yet all conducted in an arena where only the highest powers of the microscope can discern anything—that it beggars all attempts to explain, and we are tempted simply to give up the task as hopeless.

The Attempts to Reconstruct the Invisible Factories of Life

This, however, we must not do. Patient experimenters have long endeavoured to construct artificial cells, with artificial nuclei, on a large scale, from all manner of suitable materials, and to persuade these artificial nuclei to behave as real nuclei behave, under the influence of electrical forces, or magnetism, or exposure to light and so on. Enough success has attended these attempts at artificial karyokinesis to show that life uses the various forces of Nature for its purpose—though, verily, we knew that already. They do certainly suggest that electrical, magnetic, chemical, and other physical forces and laws are at work in the cell, and that they are even illustrated and employed in the purposeful series of changes by which the nucleus divides and initiates the process of life development.

But we are grossly deceived if we suppose that these experiments explain away the unparalleled character of the facts. On the contrary, the more we know in the realm of cell-life, and the more we succeed in applying the laws of not-living matter and energy to the processes of the cell, the more clearly we see that there are still further steps to the heart of the matter.

The Laws Which are Not the Creator but the Instrument of Life

Science may fully claim to have proved that life obeys and is subject to the laws and forces of the universe in general. That in itself is a tremendous generalisation, and we can never have too much detail in support of it. But the view of forty years ago, which argued from this great conclusion to the further conclusion that Life is no more than a particular illustration and consequence of mechanical laws, is no longer maintained by those who are the pioneers in this field. They will be the last to return to the obsolete and puerile view that life is lawless, capricious, arbitrary, and only connected by accident with the not-living world; but they will also be the first to proclaim that, while life obeys the laws of physics and chemistry, these are not its creator, but its instrument.

THE PATIENT TILLERS OF THE FIELDS

THE LAST FURROW—BY MR H H LA THANGUE R A This picture [illegible] Hall

THE SOWER GOES FORTH TO SOW—FROM THE PICTURE BY F. E. MICHEL

WHAT HAPPENS IN THE SOIL

The Extraordinary Story of the Busy Workers who Toil Unseen and Transform the Surface of the Earth

A MARVELLOUS FACTORY UNDER OUR FEET

We have already regarded the soil from several points of view. We have looked upon it as a battle-field in which opposing forces are always at war, as a mass of living things among which there is in constant progress a continued struggle for existence. We have seen that a constant exchange between plant and animal life takes place in the soil, and, further, that both these groups of living things at one time enrich the soil, and at another time impoverish it.

We have considered how the soil was made throughout the ages, its origin and history, the grinding of rocks and their splitting up into fragments, and we saw how, by these means, surface-soil and sub-soil are made. And we estimated the relative importance of these to the plants which use them. In studying the chemistry of the soil, we noted the different chemical factors of importance for the nutrition of plant life, learning which of these are indispensable, and how they are made, and finally we reached the conclusion that the soil we trample down so thoughtlessly must, being filled with life, contain enormous quantities of food—that it is, indeed, a veritable storehouse of nutrition for millions of living things.

We must now consider what it is that is happening in the soil which results in all these wonderful processes. The results themselves we have to some extent seen, but now comes the question—How? In other words, we have now to look at the soil as a laboratory in which an enormous number of experiments or processes are constantly being carried out. This laboratory, from our present point of view, is mainly chemical and bacteriological, so that we are brought at once to the subject of bacteria in the soil and bacteria in general, to which we must devote, at this stage, some particular attention.

The study of bacteriology is in itself comparatively recent, practically not more than forty years old, but some of the wonderful discoveries connected with the bacteriology of the soil are even more recent than that, and indicate that we are even now on the verge of more discoveries still.

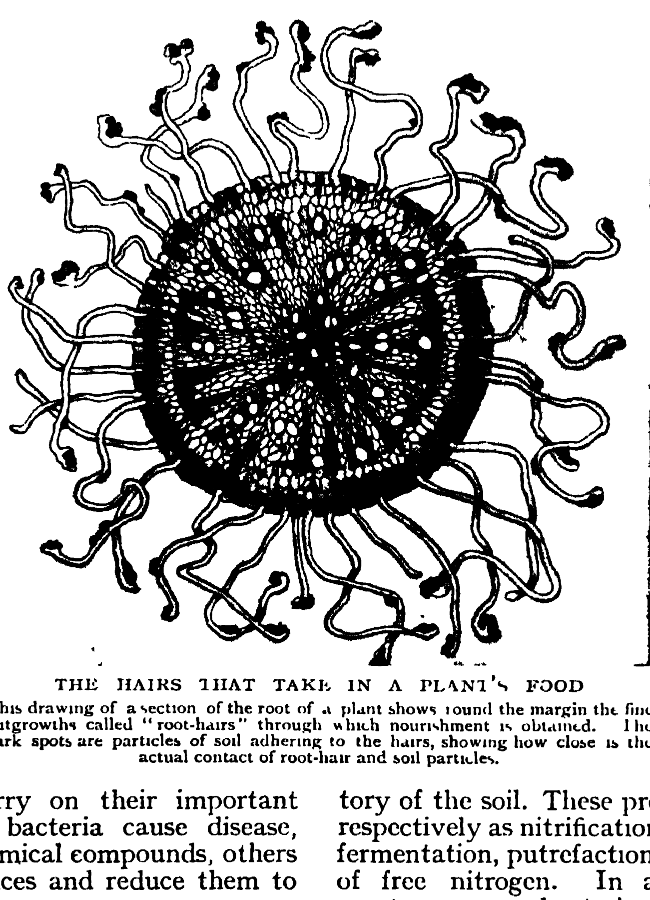
The first result of the study of this subject was undoubtedly to give people the impression that bacteria were among the worst enemies of mankind, and that most, if not all, of the ills that flesh is heir to were due to them. This impression was caused by the fact that the earliest studies of bacteriology were chiefly done by medical men in connection with disease, and in that connection the impression is a true one. It was not, however, until much later that we began to discover that, so far from all bacteria being enemies to mankind, many of them are extremely beneficial, and some of them actually indispensable. In fact, bacteria, like so many other things, may be either good or bad from the point of view of human life. It is precisely the same in connection with plants and animals. In a later chapter we shall see that many diseases of plants are due to these minute organisms, just as human diseases are, but here we may consider only those bacteria whose work is both beneficial and necessary.

Most people nowadays are aware that these bacteria are distributed universally in the world throughout air and water, existing in enormous numbers, but most people do not understand that they are just as plentiful in the soil, and as important there as elsewhere. It is this which makes the bearing of bacteriology upon agriculture so important, and the study of this subject has caused us to modify a number of our opinions and older views. We now know that bacteria are all-important for inducing decomposition in the dead bodies of plants

and animals, as well as of manure. Without their action the process of fermentation could not take place, and the soil would cease to be fertile.

Three simple points must be kept in mind in the endeavour to understand and appreciate the work which bacteria do. The first is that they are extremely small organisms which require very strong microscopic powers to render them visible, when they appear either in the shape of small spheres, or minute rods like lead pencils, or spirals like corkscrews. Secondly, they multiply and reproduce themselves with such amazing rapidity that a single microbe may produce millions like itself in twenty-four hours, being able on this account to invade very quickly all the tissues of the body of an animal or a plant. Thirdly, it has to be remembered that bacteria are just as *specific* as are other species of living things — that is to say, each microbe is a living entity perfectly distinct from others, just as distinct as is a horse from a cow or a dandelion from a pansy. It is because of this that they can carry on their important processes. Some bacteria cause disease, others build up chemical compounds, others decompose substances and reduce them to simpler forms.

The soil, then, contains myriads of microbes—or, rather, all fertile soils do so—and any soil absolutely devoid of bacterial life is useless for plant nutrition. This can be proved experimentally by the simple process of sterilising by heat a mass of soil, and so killing the microbes in it. If we do this, we find that nothing will grow in this soil. Fertility, therefore, depends upon bacteria. They are most numerous in surface soil, and become fewer in number the deeper we go down into the earth. At a depth of a few feet they cease altogether. Some faint idea of their amazing quantity may be gathered from a few figures. In the top soil, bacteria vary in number from 10,000 to 5,000,000 per gramme—a gramme being one 450th of a pound. The mind fails to grasp such numbers as these, and yet soils which have been treated artificially by manures or sewage contain far greater numbers. Such a soil has been estimated to contain 100,000,000 microbes per gramme.



THE HAIRS THAT TAKE IN A PLANT'S FOOD

This drawing of a section of the root of a plant shows round the margin the fine outgrowths called "root-hairs" through which nourishment is obtained. The dark spots are particles of soil adhering to the hairs, showing how close is the actual contact of root-hair and soil particles.

In plain words, bacteria are present everywhere in the soil, at the surface in enormous numbers, and they can be isolated from it with perfect ease. The great fact to be kept in mind in this connection is that no soil can be even moderately fertile in the absence of bacteria; and the fact that soil is known to be fertile proves in itself the presence of bacteria in great numbers. The all-important question is — What are they doing?

There are five main processes which are being carried out by these bacteria in this great laboratory of the soil. These processes are known respectively as nitrification, de-nitrification, fermentation, putrefaction, and the fixation of free nitrogen. In addition to these great processes, bacteria also play a part in the disintegration of rocks, from which the soil is derived.

Let us now turn our attention to these five great processes, and let us be very clear as to our terms.

Putrefaction is the process which takes place in the bodies of all plants and animals after death, in which a number of complex chemical substances are decomposed step by step into simpler compounds.

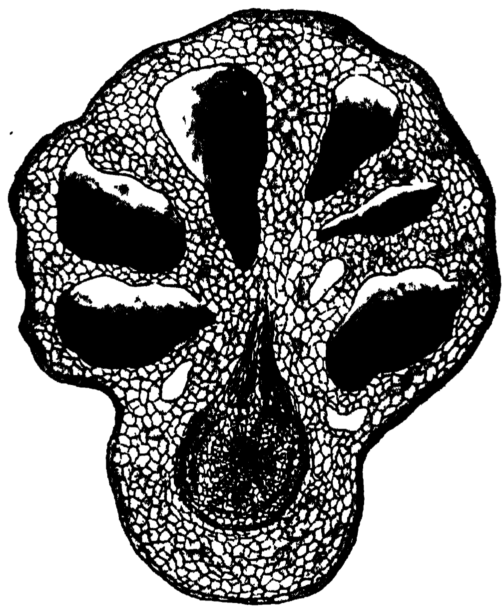
FERMENTATION describes a number of chemical changes, such as those which occur in the souring of milk and the ripening of cheese, both of which, as well as some others, are possible only when bacteria are present.

NITRIFICATION means the process by which bacteria change compounds of ammonia and nitrites into nitric acid and nitrates, the form under which plants absorb their necessary nitrogen food.

DE-NITRIFICATION is the process by which bacteria of different species are able to destroy *nitrates* and produce from them *nitrites*, which remain behind; but, in addition to these, nitric and nitrous oxides and, sometimes, free nitrogen are produced.

together can we get a true conception of what is really happening in the soil.

The whole cycle of events may be briefly summarised. Both growing plants and living animals take in oxygen and give out carbon dioxide during the process of respiration, which is, in all essential respects, similar in plants and animals. Living animals feed upon plants, such as grasses, vegetables, fruits, and so on, and by the excretion of nitrogenous matter, and by the ultimate death of their own tissues, they add to the supply of organic matter in the soil. Dead plants and leaves also add to



THE MARVELLOUS BACTERIA WHICH HAVE THE POWER OF MAKING THE NITROGEN OF THE AIR AVAILABLE FOR PLANTS

The photo-micrograph on the left shows the nitrifying bacteria hard at work, in clusters, rendering nitrogen available for the plant; the bacteria are the dark portions of the picture. The photograph on the right shows the appearance of one of the nodules made by the nitrifying bacteria, which have here finished their work, their vacant place being shown by the dark cavities.

FIXATION OF NITROGEN is the process by which the free nitrogen of the air is absorbed by bacteria and transformed for the use of the plant.

It must not be supposed for a single moment that these important bacteriological events are isolated occurrences. On the contrary, they are very closely connected with each other, and are, indeed, interdependent; and our understanding of the whole idea of the soil as a laboratory in which these processes are carried out depends upon our recognising that they are all going on at once. The wonderful relationship which exists between plant life and animal life is bound up in these events, and only by realising the way in which they are linked

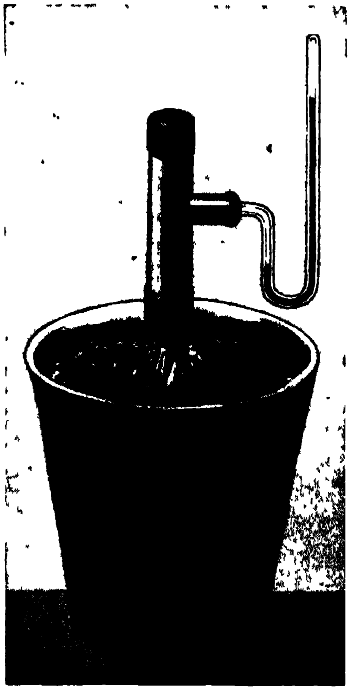
the organic matter in the soil. During the process of feeding, green plants take in the carbon dioxide from the atmosphere and return oxygen. The plant also absorbs into itself water containing the mineral salts from the soil dissolved in it.

Now, it is from this total supply of organic matter from animal and plant sources that the different kinds of bacteria produce compounds of ammonia. The bacteria act upon these compounds in such a way as to convert them into nitrites, and these, again, are acted upon by other bacteria and converted into nitrates. Other kinds of bacteria in the soil are at the same time fixing the free nitrogen of the air and also producing nitrates, and these nitrates

are dissolved in the soil and absorbed by the roots of the plant, so supplying the plant with its necessary nitrogen. Thus the body of the plant is built up. But this plant in time either dies a natural death, or is cut down, or is eaten by some animal. In either event it is ultimately once more subjected to the processes of putrefaction and decomposition as the result of bacterial action, and returns to the soil in the form of organic matter. A living animal does exactly the same. Then the cycle begins again. Here we have a complete cycle of events which never ceases, going on from day to day, from year to year, from generation to generation, throughout all time. It teaches us that the whole of living creation is dependent upon all the parts. The animal, the plant, the invisible microbe, and the so-called lifeless clod are all part of one vast process which keeps the world in continual life.

Having thoroughly grasped the idea of the interdependence of the varied processes which take place in the soil, we may look at one or two of them separately, in order to understand them a little more fully.

Let us take, first of all, the processes of fermentation and putrefaction which take place in connection with the soil. The chemical changes involved in putrefaction, which are set up by the action of ferments produced by the bacteria, are extremely complicated, and depend upon the further fact that a great proportion of the tissues of plants and animals consist of complicated albuminoid and nitrogenous compounds. The first changes which take place in these substances are frequently in the nature of the production of soluble albumens and peptones. These are still further split up into simpler compounds, and these others are in turn changed into still simpler ones. So the process goes on step by step until we reach, among other things, the evil-smelling gases which are commonly associated with putrefaction, and which escape into the surrounding medium—the air if at the surface, the soil if underneath. It must be remembered that these complicated changes of putrefaction take place not only in the bodies of animals and plants, but also in the substances which those bodies have produced. Further, it should be mentioned that in these processes of decomposition certain poisonous compounds, such as those known as ptomaines, are produced. The exact nature and quantity of the ultimate compounds resulting from putrefaction is determined by the particular kind of bacteria, and also by the fact whether oxygen is present or absent. The organism mainly responsible for these varied processes is known as *Bacterium termo*, under which several species are included. All these extremely minute germs are highly mobile.



THE PRESSURE OF A ROOT

This picture shows how the upward pressure of a root is measured. A large tube is fastened to the stump of a dahlia stem by a rubber tube. As the water rises in the dahlia stem the pressure in the tube forces up the mercury, which rises, and the differences in its level measure the root-pressure.

Let us now examine the process of nitrification, or the production of nitrates. This result — the production of nitrates from manure, the tissues of plants and animals, and so on—has long been known. It has been recognised for a long time that the organic nitrogenous compounds become burnt, or oxidised, in the soil, and that a great deal of the nitrogen contained finally assumes the form of nitrates, chiefly nitrates of calcium or potassium. In the same way, it was known that compounds of ammonia under the same natural conditions become transformed into nitrates. What was not known until modern times, however, was that these changes were due to bacteria. It is not a mere chemical change, but depends upon the fact that the soil is living. A simple experiment proves this, because if a specimen of soil be sterilised it is found that the process of nitrification does not take place. It must, therefore, be due to the living bacteria which are always present in the soil.

Whenever the complex organic substances given off from plant or animal bodies undergo nitrification, there is always an intermediate stage before the ultimate production of nitrates. That intermediate stage is represented by the formation of ammonia compounds; and it is only when these ammonia compounds are produced that the special nitrifying bacteria begin

their work. Up to that point the bacteria concerned are those of putrefaction, which again exemplifies what was mentioned before, namely, that these varied processes are interdependent. Here, again, we see the specific nature of the different kinds of microbes, some causing putrefaction and producing ammonia, others acting upon these and turning them into nitrates.

But another point is this. The whole process resulting in the formation of nitrates does not occur as one simple process, but in two distinct parts or stages. The first stage of the process is the partial oxidising of the compounds of ammonia into nitrites. Then the second and final stage occurs, in which, by a further process of burning up, these nitrites are converted into nitrates by other kinds of nitrifying bacteria. So far as is known, there is no one kind of microbe which is capable of carrying out the two parts, or stages, of this process, but each part must be done by a special organism. It is like employing two sets of skilled workmen, each of which understands only his own special work. Both are really essential before the process is complete.

A ROOT'S SEARCH FOR FOOD

It is well known that a root will search for nourishment, and this photograph shows the root of a fir tree branching at right angles in order to pass through a layer of sand to get to a more nutritive layer of mould. As long as the horizontal part of the root was in contact on its upper side with a layer of vegetable mould, it continued to grow in that direction, but directly the root became surrounded with sand it bent at right angles, and went straight down till it reached mould again.

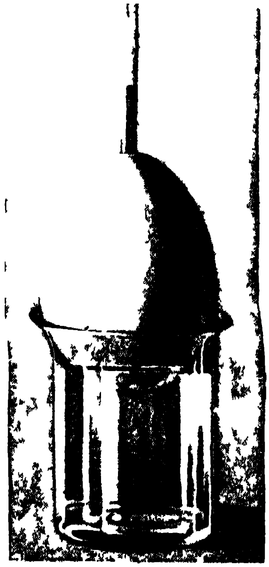
The organisms which are the actual agents in the process of nitrification are *nitrosomonas*, which is concerned in the first part of the process, and *nitrobacter*, which carries out the final stage. The first of these is an extremely small organism, possessing the power of very active movement, while the second is a stationary pear-shaped germ. Both are among the very smallest of bacteria. A very interesting fact in connection with this nitrification process is that the two parts of it would appear to be equally rapid, because it is not possible to discover free nitrites in the soil in which nitrification is taking place, which means that the nitrites are being converted into nitrates as quickly as they are produced.

These nitrifying bacteria of both kinds are found in enormous numbers near the surface of all fertile soils, and in the organic matter of rubbish and manure heaps. They can do their work rapidly, however, only in the presence of certain conditions. It is essential that they should have a good supply of oxygen and water, a suitable temperature, the absence of light, and the presence of certain alkaline salts, such as the carbonates of calcium, magnesium, or potassium. We can readily see, therefore, that it will often happen that the nitrification process is interfered with—for instance, in an excessively dry soil or season, or in a soil which, owing to the absence of proper drainage, or to its too close constitution, fails to admit air; or when the temperature falls to a very low point, as in severe winter weather. Another condition which interferes with the activity of these bacteria is the presence of organic material which has not been decomposed. In fact, nitrification can hardly be said to begin until the special organisms of fermentation have performed their part. The presence of ammonia, also, is a very potent check upon the action of the bacteria which produce the nitrates.

These wonderful little germs are therefore of vital importance to the gardener and the farmer, because nearly all the nitrogenous

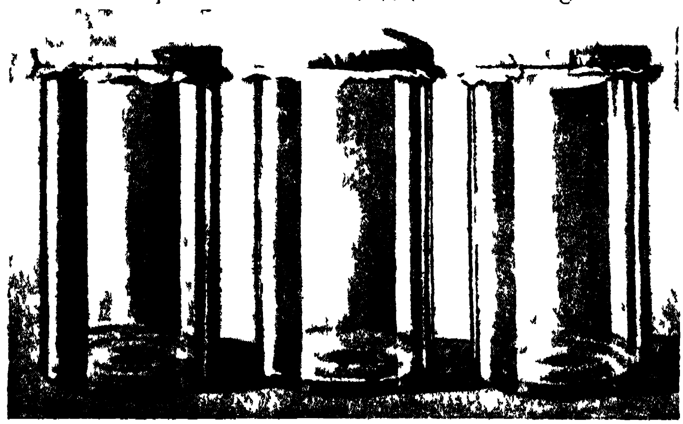
manures must undergo nitrification before they can be utilised by plants. We are justified in classing them among the greatest benefactors of the world, for without them agriculture would be impossible, and plant life would disappear.

Just as some bacteria are capable of producing nitrates in the soil, so there are a number of other species in the soil which cause these nitrates to be reduced to nitrites, and because this process is the opposite of that which we have been considering, it is termed de-nitrification. These de-nitrifying bacteria have been found to occur not only in the soil, but also in air, manure, and water. The nitrites produced remain in the medium in which the production has taken place, or gases of nitric and nitrous oxides or nitrogen itself are produced. The exact kind of de-nitrification which takes place depends partly upon particular germs connected with the process, and partly upon the presence of organic matter which can be easily oxidised. This organic matter is a necessity of the process. One striking peculiarity about these bacteria is that a good many of them belong to the group of organisms called anærobic—that is to say, they can only carry on their work in the absence of free oxygen. For this reason de-nitrification is found most actively going on in soil which contains no air or very little air.



ABSORPTION OF WATER BY LIVING MATTER

[illegible]



HOW WATER GOES THROUGH THE WALLS OF A PLANT CELL

The natural phenomenon generally known as osmosis, or the passing of moisture through the walls of a plant cell, is represented by these pictures. Three wide-mouthed jars are taken. The first is filled with sugar solution, and a piece of bladder or membrane is tied over the mouth. The whole is then submerged in water for twenty-four hours. It is then seen that the covering membrane, which was flat, bulges outwards, as in the second picture. Water has passed through it inward, though no aperture exists. If the jar is then put for some hours in water containing a stronger solution of sugar than the jar itself contains, the membrane is found to sink in, as in the third jar; water has passed through it outwards. So fluids pass through walls of plant cells.

Considering that free nitrogen is produced in this process, it might be thought that the nitrogen would be lost by escaping into the atmosphere, but the nitrates are not produced in the nitrifying process until the organic matter present has been oxidised, which means until one of the conditions necessary for the de-nitrification has ceased to exist.

The last great important process going on in this bacteriological laboratory of the soil is that of the fixation of free nitrogen, and the story of this process in detail constitutes one of the most romantic chapters in recent science. Many observers have noticed that there is an increase in the total quantity of nitrogen in soils which are not being utilised, in spite of the fact that no compounds are being added from which the supply could be augmented. It is only within recent years, however, that the startling discovery was made that this accumulation of nitrogen was actually caused by living bacteria in the soil. The wonderful truth is that in this soil there exist, in addition to all the varied bacteria we have already discussed, a number of others possessing the extraordinary capacity of being able to absorb the nitrogen in the air—to fix it, so to speak—and then further to elaborate it into nitrogenous compounds. One organism which can do this, which has been isolated and is now famous, is that known as *Clostridium pasteurianum*, described and studied by the bacteriologist Winogradski.

The most striking example of this process of fixation of nitrogen is seen in connection with certain leguminous plants, which apparently live on terms of mutual advantage with another species of bacteria. The discovery of this most interesting occurrence was made by the observation of a number of curious little nodules or tubercles on the roots of beans and other

leguminous plants, such as clover and peas. These little structures, of a pinkish colour, are oval or round, and solid when young, but later on they break up into pieces. If a section be made of one of these nodules, it is found that the cells in the middle contain quantities of bacteria. One of the illustrations on page 44 actually shows these bacteria in position. These organisms have been found to be present commonly in soils, but more especially in those in which leguminous crops—such as the pea and the bean —have been raised. They are not all of the same character, though they may possibly be really all one species. Certainly some have greater capacity for producing these nodules than have others, and those when plants themselves are flowering, after which they diminish in size and number. Then, when seed-time arrives, the nodules themselves shrivel up, though a certain number of their organisms escape and remain behind in the soil, ready in their turn to attack the next leguminous crop sown in that soil.

From the agricultural point of view, we see how important it is to the farmer to have the use of these bacteria at his disposal; and he has now discovered that the nitrogen left behind after a leguminous crop has been raised is available for subsequent crops, which in themselves are unable to use the nitrogen in the air. The development of this process will probably be very much

THE REVIVAL OF A PLANT BY WATER

These pictures show how water revives a plant. On the left the plant is drooping and withered—to all appearance dead. Water is applied and health begins to be restored, until on the right we see the plant in full vigour. All growth requires some amount of moisture.

from one kind of plant produce larger nodules on a plant of the same species than they do on another kind. That is to say, the nitrogen-fixing bacteria from the nodules on peas produce their best results on other peas, though they can also introduce this nodule formation on beans.

The enormous value of these organisms to these important crops is abundantly clear. In their absence the leguminous plants would be compelled to obtain their nitrogen exactly in the same way as do any other land plant—that is to say, in the form of nitrates principally. But with the aid of these little organisms these plants are able to make use of the free nitrogen of the air, which the bacteria fix for them. The greatest growth of these nodules takes place greater in the future by artificial means; indeed, the various kinds of bacteria capable of carrying it out are already grown artificially, and sold in cultures used for mixing with the seeds or with the soil itself. In other words, the attempt is being made to actually inoculate seeds and soil with these living bacteria, in order that they may capture the nitrogen the plants require.

Here, for the present, we must leave this fascinating subject of what is happening in the soil. We leave it with the thought that the soil is, indeed, the very beginning of all things; that in it are going on, silently and without ceasing, marvellous processes of extraordinary interest, the further investigation of which is destined to have far-reaching effects in practical agriculture.

THE WOLF APPROACHES THE CITY, LED BY THE SPECTRE OF FAMINE

In this picture Mr. J. C. Dollman has suggested the advance of the wolf to the gates of the city, led by the spectre of famine. Famine and the wolf were associated terrors in the days of early man, and so continue, in the wilder parts of Europe, to this day. When winter grips the land and lesser animal life is dormant, the grim and famished wolf still turns upon man himself.

SAVAGES AT OUR GATES

The Life-Stories of Hyenas, Wolves, Jackals, Dingoes, Foxes, and Wild Dogs

WILD LIFE ON CIVILISATION'S BORDERS

During the drought of 1911, Professor Boyd Dawkins invited his fellow-countrymen carefully to examine the desiccated margins of all the water-sheets of Great Britain. He wished us to discover traces of the lake-dwellings, of the artificial islands and other water-protected retreats, once abounding in the land, in which our ancestors, down to the time of the Roman Conquest, found sanctuary from wild beasts.

There now remain in Great Britain only the fox, a few wild cats, the stoats, and the weasels to suggest what the struggle between man and beast meant here, but the torch in the bone cavern, and the dynamite of the excavator, have revealed to us something of the story as it was when hyena and wolf helped to multiply the hazards to which our forefathers were exposed. The lake-dwellings show how he progressed, beyond the rough shelter of the woods and the scarcely more inviolate cave, to an intelligent, organised defence of family life against his natural enemies.

Down in the clay we find the remains of both striped and spotted hyena, contemporaries with animals of the same species which fought with man for possession of the caves. The descendants of like animals are now resident, as distinguished visitors, but they find their homes behind iron bars in our zoological gardens. They seem to bridge for us the vast gap in time dividing us from an England which was geographically an outpost of Europe, the coastline of the Continent, the farthest west known to ancient Europe; an England into which the hyena could roam dry-footed from Africa without one physical barrier to overcome. The spotted hyena never got far beyond eastern England, but the striped variety was among the commonest of British animals in England and Wales, though unknown in Scotland and Ireland. Now these animals are to be found only in the hottest climates. The wolf remained until relatively modern times; the raccoon is of the distant past, but the fox is still common. To complete a picture such as that in which these animals once figured in Great Britain, we have now to travel far afield, but, where they are, their habits appear to have changed so little that we can reconstruct the old-time scenes.

To-day, upon the border-line of civilisation, there skulk the same species of animals which challenged man in the long ago. The savages of Africa, and the scarcely civilised natives of remoter India, pass their lives in the midst of these beasts. They are fighting the battle for the preservation of their homes and of their flocks and herds against their animal rivals just as early man fought his battle. The Briton, pushing into the wilds to-day, finds that the frontiers of the native fauna do not merely begin where man's end; his and theirs overlap. Not consciously, but by their actions, they resent his intrusion. The game which would have been theirs vanishes at man's coming, and they make his flocks supply the deficiency. In areas where the involuntary association with animals is of long standing, we are afforded a glimpse of the means by which primitive man first came to domesticate the savages of the wild. There is a tacit understanding between man and the hyenas and the jackals. Even the fierce wolf surrenders members of its family to the homes of man.

The relations are really little changed from prehistoric times. Wolves, hyenas, and jackals hang upon the outskirts of human habitations, as robbers, as tolerated snappers-up of trifles; here and there one of their number becomes an inmate of the human settlement, and we see how man got the dog. But the untamed majority are

relentless pillagers of flocks, and show us how man would first experience the need of a fierce and resolute animal, devoted to his interests, capable of driving off marauders.

At first sight it might be assumed that the hyena holds some sort of relationship to the dog, the wolf, and the jackal, but it is another triumph for the comparative anatomist to have traced the descent of this animal. The hyena's nearest relative is the aard-wolf. Together they trace back, not to the dog tribe, but to the civet family. Of course, the families are quite distinct to-day, but in the story of their descent, so closely do the forms approximate, it is impossible to say where civet ends and hyena begins.

The Wild Life that Prowls in the Ruins of Cities

The hyena has gone through life by proving that he who fights and runs away lives to fight another day. Three distinct species flourish—the striped, the brown, and the spotted. The first is common to Asia and Africa, with domiciliary habits varying with its habitat. It may occasionally frequent forests, but it is more commonly found in sandy and rocky plains. It is the ghoul of the rock-cut tombs of Palestine and Syria; in India it is to be found lurking in cities once teeming with human life, or, still more frequently, in caves and rocks. The brown hyena is a South African species, fewest in number and more restricted in range. The spotted species, the unloved king of the family, ranges widely over Africa. It was once in India; it abounded in most parts of Europe. It must have been a rare moment in the life of the naturalist who was first able to prove that the bones of the hyenas belonging to a distant epoch were those of animals specifically identical with the spotted hyenas of to-day—a little larger, perhaps, but not different in any other way.

The Cowardly Hyena which Flies from a Healthy Man and Lurks in the Track of a Vulture

By this fighting and running away have the hyenas, now divided into three species, maintained a good place in the battle of life. The spotted hyena, the most powerful of the family, is one of the most hated of animals. It is such a coward, yet so cruel. Associated in loud-howling packs, it will on occasion show considerable skill in the capture of its prey, but it is the sneak-thief of wild life. Sheep and goats it will take, of course, and not be blamed unduly, but there is something revolting in the way in which, fleeing like a phantom from a healthy man, it will kill and carry off a sick man, or snap up a tiny child. With its great bodily strength, it unites unequalled power of jaw, enabling it to crack the shinbone of an ox with as little difficulty as a dog can crunch the bone of a fowl.

This power of the hyena is generally referred to its superb teeth, but it is sometimes forgotten that the vertebræ of the neck are furnished with muscles so developed as make the entire neck appear to possess but a single joint. But the animal, fortunately for mankind, does not appear to realise its own strength. It can and does kill many animals, but its nature is to follow in the wake of other carnivores, and to make a meal of the skeleton which they and the vultures have picked clean. A hyena would be conspicuous by its absence when a small hunting-party was on the move, but it would be a demon of death and destruction on a battlefield where wounded men lay helpless.

An animal which is a coward must call cunning to its aid, and so the hyena does. It will bite the face of a sleeping man—which is, perhaps, rather a bold proceeding for so timorous a beast—but its supreme cunning is shown in its attacks on the natives of Northern Angoniland.

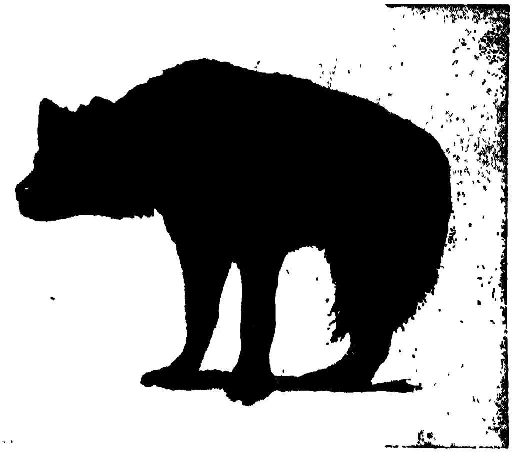
The Terrible Scavengers that Prowl about the Towns of Abyssinia

Whether its method is peculiar to the hyenas of that part, the Zambesi River, in Rhodesia, or whether the native huts are specially favourable to the plan, we do not know, but there the hyena is dreaded for the assaults it makes upon the natives in the early morning. Not in the open does this happen; the wily beast knows that to leave his hut a man must kneel and crawl out, almost on his hands and knees. So the hyena waits, and as a head pops out from a low doorway it makes its grab.

Yet, with all its detestable qualities, the hyena has its pact with man. In Abyssinia, where the animals are abnormally plentiful, they are the chief scavengers; and though it ravages flocks right and left, and is cordially hated, the natives regard the hyena as a necessary evil, and actually cut holes in the walls of their towns so that, when all is quiet at night, the unclean hyena may steal in and eat the filthy garbage which the housewife throws into the street. That sort of agreement between man and these animals has probably been in force a hundred thousand years. The style of human dwelling has altered—that is all. The offal and the hyena have always been there.

The aard-wolf, akin to the hyena, is a curious animal which has caused the

THE STRIPED HYENA



THE SPOTTED HYENA

With its enormously powerful jaws the hyena should be among the mo idable of animals. It is, in a way, but as a sneak-thief and as the assailant of wounded or dying prey Starting from th e ancestry with the civet, the hyena has developed into the supreme disposer of bones, and present-day species crack ox-bon as did their ... stors in old-time British

naturalist some perplexity. Arising from the same stock, it has branched off to fill a sort of intermediate position between the carnivorous and the insect-eating animals. With singular and degenerate teeth, it makes its meal of carrion and white ants; it burrows, it comes out only at night, and it flees like a hare if disturbed. It is a singular beast, descended with the civets, resembling the hyena in many points, but having more toes than its cousin, and showing a head something like that of the mungoose. It was said to inhabit only South Africa, but its range is now found to be wider. Indeed, there is a good deal to be emended in even modern natural history as to the habitat of night-wandering animals. The flashlight camera has revealed animals in localities where they had never been suspected of existing.

We owe nothing to the hyena or the aard-wolf save the service they render in savage or semi-civilised lands as scavengers. But the case is different with the dog family. Here we have grim and terrible enemies in the wolves, and unclean, skulking beasts in the jackals; we have the robber of hen-roosts in the fox, but we have also the dogs proper. With the wolves and the jackals, possibly producing a general type of which the dingo may be a modern representative, man set out to rule the earth, to become a flockmaster and a stockkeeper. The dog family is so generalised that it is difficult to trace the line of descent back to any one primitive mammal, but, taking wolf and jackal as we find them, we credit them with the parentage of all our dogs, from the lordly mastiff to the tiniest pet that any lady does her best to make unhealthy by coddling in her boudoir.

THE EGYPTIAN JACKAL

Of this widely distributed group of animals the Egyptian jackal is the largest, with a height at the shoulders of sixteen inches, and a decidedly wolf-like outline.

We must view the wolf, therefore, with some little respect for the boon that he has indirectly conferred upon the human family. A sort of civic life may have begun by his aid. As an old poacher makes the best gamekeeper, so the first wolves that became domesticated were the best animal friends man could have for the preservation of his flocks, his home, and his children from the onslaught of the rest of the wolves. Most animals have what may be called the proprietorial sense. The most timorous bird will boldly assail a larger and more formidable rival which is put into its cage. A cat will attack another cat trespassing into its home. The cat will even assault an animal of a different species for the same reason, for the writer has a vivid recollection of a cat's furiously attacking a Shetland pony in whose favour a horse had been ejected from its loose-box. Puss, the friend of the evicted animal, sank her claws with such force into the muzzle of the Shetland

as to draw blood. Had some early cat shown the same spirit under like conditions, cats might perhaps by this time have been trained as guardians of human homes, second only in importance to the dog itself.

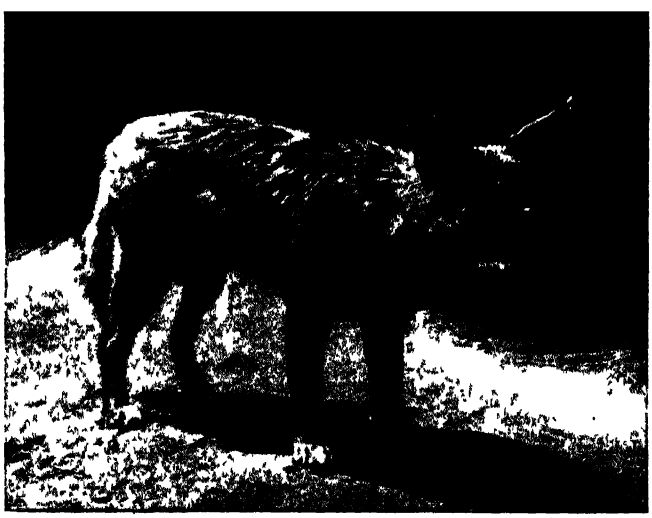
But the dog has this sense of proprietorship more strongly developed than any other animal. The meanest cur is a little hero in defence of its kennel and of its master's home. The instinct is developed from the wolf's fierce resentment at any interference with its prey, or any intrusion upon its home. A cat will teach its kittens to kill mice, but a dog will fly at its puppies if they challenge its right to kill a rat. And the old-time wolf which man had trained from its infancy in his habitation would fly at other wolves that it might meet on the prowl. The custodian of the home would desert, no doubt, and rejoin its friends of the forest at times, but its cubs would be born at home, and, once there, no competitor from the wild beyond would be tolerated. The association between man and wolves would spring up in course of time upon some such lines as those which govern man's relations with the hyena to-day. There was ample choice, for wolves abounded throughout Great Britain. They were not exterminated in Ireland and Scotland until the latter half of the eighteenth century, though the last English wolf died towards the close of the fifteenth century.

A FOX IN THE BRACKEN

The fox, in his contest with man, has been driven to life underground, and when he is to be hunted his "earth" is stopped up at night while he is prowling abroad

The Eskimo dogs, and the dogs of the Indians in the south-western States of North America, are derived directly from domesticated wolves; and Sir Harry Johnston identifies certain dogs in Achill Island, off the West Coast of Ireland, as simply stunted wolves, agreeing with the wolf in colour, in brush, in the shape of the ears, and in the arrangement of the masses of hair along the line of the back. The idea is feasible enough, seeing that the true wolf exists to-day in France and Germany and Spain, and elsewhere in Europe, and in times of severe weather becomes a terrible scourge in Russia.

With the exception of the wolves of the Falkland Islands, the wolf family is confined to the Northern Hemisphere. It is unknown in Africa and in South America. The monarch of the tribe is the great Alaskan wolf. Mr. Hudson awards the palm to the American timber wolf, but he must have overlooked the Alaskan representative, which, from muzzle to tip of tail, measures 5 feet 10 inches, and stands $31\frac{1}{2}$ inches high—bigger than some Shetland ponies.



THE HANDSOME JACKAL

This black-backed jackal is the handsomest of the jackals. The beauty of his coat is the more notable when it is remembered how offensive is his normal diet.

The photographs in these pages are by W. P Dando, Donald McLeish, and others.

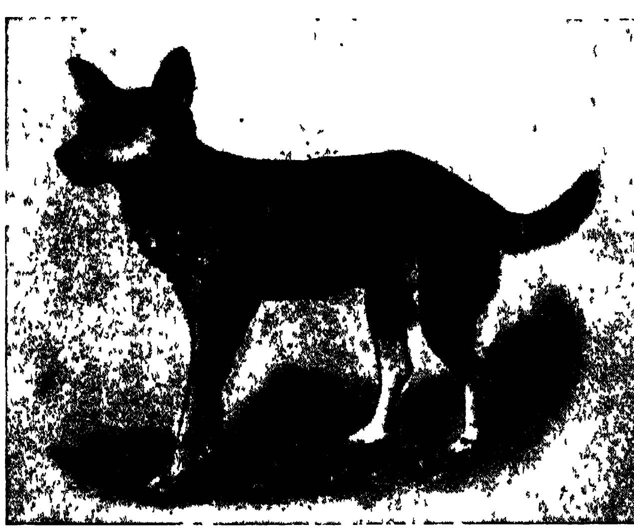
The European and American wolves agree in their habits. They frequent open country and forests; they make their lair in rocky caverns, in the decayed trunk of some fallen tree; they even make burrows in the ground, or enlarge those begun by other animals. The wolf has no friend in the world, for he lives, when near

civilisation, at the expense of man's flocks, and at the cost of human life. The famished lone wolf will attack a man at night; the pack of wolves in winter is the terror of travellers by road. Their ferocity when pressed by hunger is as unappeasable as their strength and endurance are inexhaustible. Their speed may have been exaggerated. Experience proves that they cannot outpace the greyhound, but they can run down the horse; and of the stories of their pursuit and capture of sledging-parties not the half has been told.

UNLOVELY FREAKS—A PAIR OF MEXICAN HAIRLESS DOGS

Hairless dogs, which are the unaccountable choice of certain fanciers, are found in South and Central America, China, Manila, the Antilles and Bahamas.

Every year the fight of the wolf for existence must become more precarious, for civilisation and wolves are incompatible. It is not unusual for them in winter bodily to invade a village. The reason for their successful struggle against extermination is partly that they can exist on a varied diet, and partly that they are exceedingly prolific. The female wolf brings forth from six to ten cubs at a time; she rears them with rare fidelity. Whether there is any truth in the legend of wolf-reared children is a much-debated point. Italy, the home of more than one delusion, still keeps a live wolf in honour in a den within her walls, to celebrate the rearing of Romulus and Remus; and seeing the extraordinary cases of foster parentage among animals reported from time to time, there may perhaps be some foundation for such legends. One peculiarity helps the tradition in the case of the wolf. The great cats are all rough-tongued. They wash their cubs by licking them. Such treatment would rasp the flesh from the body of a child. Now, all the members of the dog-family are smooth-tongued, so any washing process would be harmless.



A SCAPEGRACE—THE PARIAH DOG

Pariah dogs are backsliders. They or their parents were domesticated. They have run wild, interbred with wolves and hyenas and true wild dogs, and have become scavengers and thieves.

The wolf in captivity requires from three to four pounds of flesh per day to keep it in good condition, but when at liberty, consuming energy rapidly in its extended forays, the animal would need considerably more than this, with fasts sandwiched between feasts. A child's only hope of escape from death would be on some occasion when the wolf had fed well, and was carrying home prey to its young. In India the native wolf, rather smaller than the European, and less bold—though apt to act in concert for an attack upon a man—frequently carries away children. Nowhere is the story of wolf-reared children more prevalent than in India. Native evidence as to animals is, as a rule, very unreliable, but there is just the shadow of possibility that from the multitude of cases reported a genuine instance might be found. Lord Wolseley, at any rate, believes in the story.

The jackals may be traced through the coyote and the Indian wolf to relationship with the true wolves. They are a widely distributed family, common to Asia, Africa, and even part of Europe. The common jackal ranges from Burma and India through South-Western Asia to South-

A SIGHT ONCE FAMILIAR IN ENGLAND—A PURSUIT BY A PACK OF WOLVES

The Saxon name for January was "wolf month," because people were "wont always in that month to be more in danger to be devoured by wolves, as, through the extremity of cold and snow, these ravenous creatures could not find other beastes sufficient to feed upon" During a recent winter wolves killed 161 people and 108,000 cattle in Russia, and the memory of their depredations still lives in such English names as Wolverton and Woolmer [This painting is by Mr R Morley]

Eastern Europe, but south of the Sahara its place is taken by certain allied forms, such as the side-striped jackal and the black-backed jackal. The largest member of the group is the Egyptian, which has a height of 16 inches at the shoulder, and a total length of rather more than four feet. The Morocco jackal is smaller and lighter built, with a decidedly intelligent head of the true canine type. The handsomest of all, however, is the black-backed or silver-backed. The jackal is practically omnivorous; and its appearance makes one marvel at the power of the organism of the animal to convert unpromising material to such good use. There is no offal too foul for the jackal to relish, yet, in spite of its unspeakable diet, the animal carries a magnificent coat, with every appearance of good health and keen enjoyment of life.

Although there is no relationship between the jackal and the hyena, there is much in common in the habits of the two. The jackal is another of the sneak-thieves of creation, wanton, cowardly, attacking wounded game—a merciful form of cruelty, by the way—snapping off the fat tail of a sheep, and then running away, to leave the victim suffering. Like one or two other carnivorous animals it will eat readily of vegetable substances, and plays havoc with sugar plantations, destroying a dozen times as much as it eats.

The Way in which the Jackal has been of Service to Man for Thousands of Years

It is an interesting and singular fact that the jackal appears to flourish from association with man. It does not voluntarily make its home near him, it is true, though it lurks in the cities that he has built and deserted. But it is as a scavenger in the track of the hunter that it most profits. Where the man with the gun has been, the jackal follows, and the hyena comes along for the bones. And for the time being, at all events, jackals become more numerous in areas where big game is hunted and killed. As a scavenger, the jackal has its apologists, on the ground that, where all knowledge of sanitation is absent, even an animal which howls nightly through the streets, devouring refuse, is not to be despised. In that sense the jackal is of service to man, as it has been for thousands of years, and on precisely the same terms. But it levies heavy toll on poultry, lambs, and kids.

The jackal has the weirdest of cries; and a pack of these animals wailing in chorus makes the blood of a man new to their music run cold. "Dead Hindoo, where, where, where?" is the not inapt word version of their cry; and the phrase is possibly true to the meaning of the jackal interrogatory, for he is a notorious rifler of graves.

The dingo, the so-called aboriginal dog of Australia, comes next in order, between the jackals and the true dogs. Smaller than the wolf, on moderately tall legs, with a short, broad muzzle, well-developed ears, and a rather long and bushy tail, the dingo is an interesting puzzle. It is the only big non-marsupial in the island-continent.

The Native Dog of Australia, which has Every Man's Hand Against Him

How could this one animal, so vitally differentiated from the rest, producing its young in the manner common to mammals, have been evolved in Australia? The first answer was that it was a recent importation. That did very well for a time, but now fossil remains of the dingo have been discovered in some of the superficial and cavern deposits of the country, in company with remains of species now extinct. Now, this means that the dingo reached Australia unassisted, in some manner not yet understood, or that it was taken there by man in early times.

Possibly this suggestion of man's company is not so wide of the truth as may appear, for it is reported that dingo remains have been discovered with the remains of man. Meanwhile the lineage of the dingo is involved in some mystery. An edict has gone forth decreeing his extermination. He is a scourge to sheep and poultry, and kills with savage wantonness. So the Australian Government has pronounced sentence, and the hands of all men are against him. His blood will not die out, for, like the jackal and the wolf, he breeds freely with the domesticated dog. But he is as true a nomad as they, and to keep a full-blooded dingo permanently about a house is impossible. The time comes when he hears the wild voices of the night calling him, and away to freedom and the wilderness he goes, to become a poultry-thief.

The Curious "Wild Dog," which Sleeps through the Winter without Food

There are many so-called wild dogs. The naturalist objects to this term, asserting that the wolves and jackals are truly the wild dogs. But there is no other generic name for these other groups, and fashion has given them the name that is generally used. The curious raccoon dog, of China and Japan, is a great curiosity, with long and pointed muzzle, small, rounded ears, with a body slender and arched, set up

on short legs, the whole appearance suggesting the raccoon. In the summer this dog lives on mice and other small animals, and in the winter catches fish at such places as broken ice affords. More generally, however, the raccoon dog hibernates, a remarkable departure from the habit of a numerous and widely distributed group of animals. As this dog is one of the least formidable of the family, it is not unfitting that he alone should possess this power peacefully to snooze away the winter, regardless of food.

The Remarkable Intelligence of the Wild Hunting Dogs of India and Africa

India and Siberia and Africa have each their wild hunting dogs. The Siberian representative is a fine-looking beast, and, like its African cousin, hunts in packs. The intelligence shown by the African hunting dog in pursuit of its prey has been noted by many observers, but the Indian dogs are every bit as courageous and adroit, and are credited on good authority with occasionally attacking and killing both the leopard and tiger.

If they get a leopard on the run the plan is for two of the biggest dogs of the pack to chase, one on each side of the quarry, while the others pound away in the rear. Every now and again, " as if by signal from one of the leaders," the dogs in the rear close in and make a general attack, then draw off. This is repeated again and again until the larger animal is weak by loss of blood and successive struggles, when the end is not long delayed. This policy of assault and retreat tallies with a description, by Mr. Selous, of an attack by a single African hunting dog upon a fine sable antelope. The dog would close in and inflict a bite, then hang back for the antelope to continue its flight, keeping close behind, until ready to make another onslaught.

The Bold Strategy and the Audacious Cunning of the Fox

The fox, with which our chapter closes, is too well known, so far as the British species is concerned, to need much description. Neither is it necessary to produce new evidence in support of its character for cunning and audacity, its skill in evading its enemies and their arts, its bold strategy in pursuit of its prey. That prey embraces the widest range of animal diet—hares, rabbits, pheasants, partridges, lambs, rats, mice, moles; any bird which stealth and swiftness may enable it to surprise; carrion, fish; even frogs, beetles, and worms, as well as shellfish and crabs. To domestic poultry it is a devastating enemy, as every poultry farmer in hunting country knows only too well. Sir Harry Johnston, who has known foxes to clear a lake of swans, mentions that in the West of Ireland these rapacious animals kill the foals of the mountain ponies. That it is one of the very few animals which can extract a meal from the well-protected carcase of the hedgehog speaks volumes for its skill in mastering the food problem, for the fox is tender-snouted, and yet must bring its snout in contact with sharp and penetrating spines.

With a diet so varied, reinforced by vegetable additions, the fox was bound to make a bold bid for his place in the scheme of animal life, and he has had a long and prosperous career. His family is almost world-wide in distribution, so that it is easier to mention where he is not represented than where he is. Although unknown to South America, the fox has its home in the northern half of the New World, in Africa, Asia, and in Europe. Australia is excluded from the map of its territory, and there are some islands from which it is a notable absentee.

The Fox of the English Shire, the African Wild, and the Eastern Desert

But in the desert lands of Asia, in the wilds of Africa, in the frozen wastes of the Arctic regions, in the torrid lands of the tropics, the fox is a well-marked feature of the fauna. The character of its home varies with the animal's surroundings. Most foxes have a powerful scent, and it is by this that they are hunted by hounds, but in India the fox, to a great extent, lacks this tell-tale clue, and so there the greyhound, the dog which hunts by sight and not by scent, is employed. In other lands, even in England, the fate of the fox trembles in the balance. The fact that he still maintains his ground in many a British shire, where he is included among the " vermin," is a striking tribute to his cunning and audacity. And one must always feel some small regard for an animal which has the engaging impudence to turn up at night, when all is safe, to rob the henroost of the chief whip of a first-rate pack of foxhounds.

There are two or three interesting species of foxes in addition to our own licensed bandit. The desert foxes have a claim to consideration, as reminding us that the desert has still its own fauna. Then there is a small grey fox, ranging from the United States to Central America, which climbs a tree when pursued, and is said to practise climbing also in pursuit of persim-

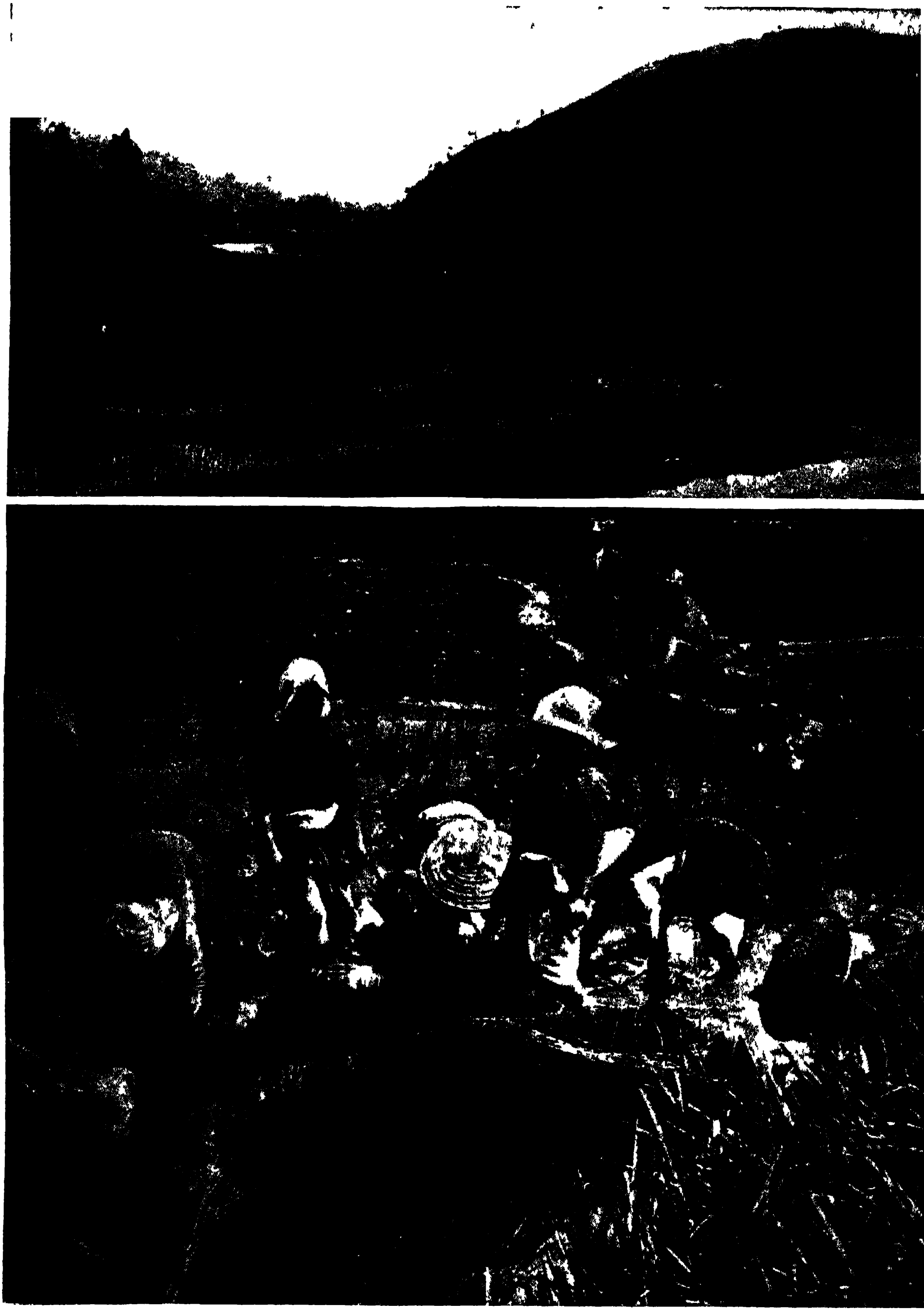
ONE OF THE FAMOUS ST BERNARD DOGS WHICH SAVE THE LIVES OF TRAVELLERS LOST IN THE ALPS

A hundred fanciers would have probably a hundred favourite breeds of dogs but all unite in common admiration of this noblest descendant of the wolf the St Bernard dog, which exists solely to save the lives of travellers snow bound and dying in the pitiless Alps This photograph shows one of these brave creatures with one of the monks who keep them in the famous alpine hostel of St Bernard

mons and grapes Arctic foxes too, are highly interesting animals, notable for their striking change from bluish summer to pure white winter coat, and also for a certain communal instinct which causes them to associate in colonies, where, it is said, they lay up a store of food for the winter The South African fox, remarkable for the extreme length of its ears, seems to mark the dividing line between the foxes and the fennecs—pretty little animals of the Sahara, ranging from Nubia to Algeria The fennec has a still greater development of ear than the chama fox, though there is no evidence to show that its hearing is more acute than that of our own red rover

An extremely interesting discovery concerning the fox is the existence upon its skin of distinct vestiges of what must once have been a scaly armour, indicating that foxes are descended from ancestors with horny scales like the outer covering of the scaly ant-eater So that when we think of fox-hunting as an ancient institution, and the foxhound as one of our natural glories, we are brought by this new knowledge to remembrance of the fact that our hounds are an artificial product, evolved by man's selective art from the domesticated descendant of wolf and jackal, that the fox and the ancestors of the hound were cousins, and that the fox bears upon his hide one of the last persistent clues to the origin of this great family The domestic dog is as much an artificial product as a carnation, but the fox bears the impress of an ancestral stock which emerged when reptiles were struggling to become mammals.

GROWING THE FOOD OF THE YELLOW RACES



THE GREAT RICEFIELDS OF THE EAST, CORRESPONDING TO THE WHEATFIELDS OF THE WEST

Rice is the staple food of the peoples belonging to the yellow race. It is inferior in nutritive value to wheat, the staple food of the white race. It is thought that this difference of diet may in some way account for the difference in the characteristics of the two races.

THE DOMINANT PEOPLES

The Passing of the Pure Race, and the Blending of Groups into Great and Dominant Peoples

THE GREAT RACE THAT DOES GREAT THINGS

IN considering the lower or primitive races of mankind, we found them on the whole so well marked and so evidently contrasted with ourselves that no argument need arise as to what we really mean, or are entitled to mean, by the word "race." Our difficulties in that respect are at hand, however; and if we are to discuss the great races with any profit we must face them, especially in view of the fact that modern critics, such as M. Jean Finot, in his "Race Prejudice," are levelling most effective attacks against the older anthropology and its confident pronouncements on the question of race.

Our difficulty is really the same as that which now faces the biologists when they talk of species. So long as forms of animal and vegetable life are far enough apart, the fact that they are of different species is evident, but when we compare forms which are more closely allied, we begin to find that our demarcations break down. Above all do we find ourselves beaten when there has been any intercrossing between the species we are comparing. We may, if we will, ignore the individual mongrel dog or the hybrid pea, but if we find a new species or a new race, or a new variety, founded in this fashion, we can ignore it no longer.

All men belong, of course, to one species, but within its limits we do certainly find various races. There is no doubt about it if we compare a negro and a Norwegian, a Japanese and a Scottish Highlander. Similarly, we may contrast a Russian and a Chinaman, but it is said that if you scratch a Russian you find a Tartar, and it may be a problem exactly to delimit the Tartar and the Chinaman. In other words, our notions of race are imperilled directly we begin to examine the boundaries between races, and they can only be maintained without fear when we deal with populations that have for ages been isolated. We find, as the gardener finds, that we can no longer decide where to draw the lines.

Within recent years biologists, as they tell us, have come to see that the idea of species is an artificial and, in a sense, an unreal one. The studies which are nowadays commonly called Mendelian teach us to look upon any individual as a living mosaic, composed of a certain combination of factors. In every individual the exact combination varies, but so long as it varies within certain limits we agree that all the individuals within those limits belong to the same species. That is the most that we can say; and obviously it teaches that, though types may vary widely in some cases, and less in others, there is no absolute break in living Nature, and we speak of species only for convenience.

If this be true *between* species, much more must it be true *within* the limits of any species, such as man. Indeed, it has not yet been realised how far the Mendelian discovery, and the new conception of species which we owe to it, have cut the ground from under the feet of those anthropologists who still hold by the older ideas of race. Much more must those older ideas be abandoned when we discover that, with the exception of very few, numerically small, and humble peoples—isolated, and therefore backward, if for no other reason—all so-called races of mankind are, so to say, hopelessly mixed. We may suppose, if we will, that in time long past pure races of man existed. Probably we have no reason to suppose so. But, at any rate, it is idle to look for such races now, least of all among the dominant peoples of the earth. If we discover men on an island a thousand miles from anywhere, we may have something which we may call a—comparatively—pure

race, but to look for such among the great peoples of the earth is now hopeless, and must for many ages have been hopeless. Man's tendency to wander and to conquer, and the intermingling of conquerors and conquered, which is perhaps the most important effect of war—these have long ago mingled strains of men inextricably. If the process ceased, and all immigration into Ireland or Switzerland or Japan were to be forbidden for a sufficient number of generations, we might expect a definite type of men to be produced by inbreeding and by the particular environment in question, and that we might call a race. How much the term would mean, and how long the identity of that race would remain if its members were scattered, would, however, be well open to doubt.

We do not need to go very far for illustration of the proposition, here advanced, that, roughly speaking, the primitive races are more or less pure, and the great races, so-called, are blends. Assuming for the moment what must afterwards be proved, that the Japanese are one of the great races, let us consider the case of the two little groups of islands, one on each side of the great Eurasian continent, which are inhabited respectively by the "Anglo-Saxon race" and its latest allies, the Japanese.

The Blend of Races which Have Gone to the Making of the Anglo-Saxon People

These islanders are now in the forefront of the world. Where, among them, shall we go for people of the purest stock?

Undoubtedly the nearest approach to a pure race in the British Isles and in Japan is to be found among their most primitive inhabitants. Perhaps in the Outer Hebrides, or some such remote part of these islands, whose inhabitants are but two or three generations removed from the Stone Age, we might find a comparatively pure stock of people; or on the West Coast of Ireland, which contributes inappreciably to civilisation. But the so-called Anglo-Saxon race, which is one of the great races of mankind, we find to be a blend of the primitive inhabitants of these islands, Celts, Angles, Saxons, Danes, Normans, Romans, with a dash of half a dozen other peoples. To call this a race in any real sense of the word is ridiculous. It is a blend, perhaps the finest in the world, perhaps not, but a blend in any case.

Compare our allies' case with our own. If we want a real race in Japan, we have no choice but to take the Ainu or "hairy Ainos," who are the aboriginal inhabitants of the islands, and may originally have inhabited them, and been confined to them, ever since they were islands at all. But as for the Japanese themselves, they are as much of a blend as we are—Ainu and Chinese and Malay and other strains compose them. The primitive race is relatively pure, the great race is greatly mixed; had the islanders never been invaded and conquered and commingled, perhaps they would be "ancient Britons" and "hairy Ainos" still.

The Things that Have Nothing to do with the Greatness of a Race

But when all is said and done by way of criticising the idea of "race," good reason remains to study the great races of mankind and to learn all we can about them. We shall learn much more from having examined what we mean by race in this connection, and we shall be more likely to face with equanimity the sociological and political possibilities of the future. And in the first place we must agree as to what people we shall include in the category of great races.

We cannot go by numbers certainly, here or anywhere else. Numerous races, and races which comprise but a few thousands or millions of individuals, are worth study for their numbers or their lack of numbers, but this has nothing to do with what we are now considering; and on such a reckoning the negroes would be a great race and the Jews a primitive race, which is absurd. Nor can we go by colour of skin, for that is but skin deep, and we are dealing with man, who is essentially man's brain, not man's skin. Buddha was brown, and belonged to an indubitably great race; Jews may be almost black, or blue-eyed and fair; the Japanese are yellow and the English white. Stature, type of hair, jaws, trunk, and so forth—all these fail us.

"By Their Fruits Ye Shall Know the Races of the World"

We can learn something from the capacity of the skull, but not very much, for brains may be much folded in small skulls, or less folded in large skulls, and it is the extent of brain surface that tells. With the older anthropologists, we may divide men according as whether they are short-headed or long-headed, or neither short nor long-headed, and may give the palm to the particular type of head which we possess ourselves, as there is reason to suppose has been the anthropological practice; but if we find that skull-form changes in a generation or two in changed environment,

what sort of calculations can possibly be built upon such foundations ?

Evidently there is only one test by which we can distinguish the great races: "By their fruits ye shall know them." A great man is not one who fills a great place, but one who does great things. A great race is not a numerous race, nor a powerful race, nor a white nor a black, a large or a small, a long or a broad headed. It is a race that does great things.

This, of course, merely raises a new question—what are great things ? Thus for many ages the Japanese had a highly developed society, noble traditions and practice, a high standard of family life, a culture which was notable in poetry, unrivalled in the garden, unique and exquisite in art. No one took any account of them. Later, they repealed the laws whereby they had so long guaranteed the isolation of their country, copied European ways, and achieved success in the arts of machinery and warfare probably at the cost of much of their characteristic greatness. They were immediately reckoned a great race.

The Greatness of the Yellow Race in the Serious Things of Life

The case really does not need any sort of argument, since we are now all agreed as to the Japanese title to inclusion in that category ; but a pretty problem might arise if we were to meet a race which was like the Japanese of 1850. This is precisely the difficulty which might have met us in the case of the Chinese, but they are so numerous that most people will grant their greatness on that account, though they have not yet beaten a European country in war.

There is, indeed, no reason why the yellow race should not be considered here as a representative example of what we mean by a great race. This race is not only great on account of its achievements in civilisation, in philosophy, in ethics, and in science, but it is certainly great in numbers, if that be taken into account, for it is much the most numerous race in the world. It appears from the most recent census that the population of China has been considerably over-estimated, but, even so, the yellow or Mongolian peoples outnumber any other.

The various members of this race conform to a certain physical type, though they differ from one another in various parts of the world no less than do the members of the so-called white race. The Chinese may be tall as compared with the Japanese, but both have a yellowish tint of skin, straight black hair, prominent cheek-bones, and the oblique Mongolian eye—which last, however, is only present in a percentage of these people, and a much smaller percentage than we commonly suppose. They have themselves contributed to the general impression that all yellow people have this peculiar structure of the eye —or, rather, of the eyelids—by having emphasised it so consistently in their art. The element of caricature is never absent, however, from Chinese and Japanese representations of the human face and person, and the Mongolian eye is neither so constant, nor, when present, anything like so marked in reality as Mongolian art would suggest.

The Appearance of the Mongolian Eye in Members of the White Races

It is a fact of much interest, hitherto wholly unexplained, that members of the white race are occasionally born with well-marked Mongolian eyes. These individuals are usually the last of a very large family, the members of which have been born in rapid succession, with much consequent exhaustion to the mother. The brain in such cases develops imperfectly, and the result is a wholly incurable and hopeless form of mental defect which is known as Mongolian idiocy, in allusion to the most obvious characteristic of the face. It need hardly be insisted, however, that Mongolians are as intelligent as any kinds of human beings, and the moral of the case is to beware of judging by externals. These afflicted people have the Mongolian eye, but anything rather than the Mongolian brain, which is of a very high order.

The principal members of the yellow race —which is really, of course, the yellow group of races—are the Chinese and the Japanese, who, between them, constitute the overwhelming majority of its units.

The Barrier to the Progress of a People Isolated from the Life of the World

Very great interest attaches, nevertheless, to at least two offshoots of this race, none the less because we shall not find it easy to recognise the greatness of the race as these illustrate it. They are the Eskimos and the North American Indians. The indigenous human inhabitants of the North Polar region, and of the New World, are derived from the yellow stock. They scarcely exhibit more evidence of greatness than is shown by their boldness and hardiness in leaving their warm Asiatic home for such distances and solitudes and rigours.

In them we see illustrated the proposition that isolation of a people, as of an individual,

puts a barrier to progress. This does not mean, for instance, that the solitary student cannot progress. He may merely resign the company of the living for that of the dead, who, if well chosen, are usually so very much more alive. Isolated from books, however, or from his memory of them, the solitary man reverts inevitably to the primitive state. So with an isolated people, or with any isolated class among a people, they cease to progress, or may actually revert. Be it noted also that such a people as the Eskimos have, by the very conditions of their life, set themselves too hard a problem for mankind.

How the Vital Energy of the Eskimos is Spent in Maintaining Mere Existence

Descended from tropical or sub-tropical forms of life, they have advanced not merely to the temperate zone, which has witnessed the *whole* of man's triumphs, but beyond it to the Arctic confines, where the organic life of man, still demanding a blood temperature of 98½ degrees Fahrenheit, can only be maintained at the sacrifice of almost everything which is more than organic. The vital energy has to concentrate itself upon resistance to cold, and maintenance of heat by the deposition of much fat under the skin, by the absorption and digestion of very large quantities of food, notably fatty food, with which the human stomach cannot deal at all, and which requires so much time and energy for its digestion.

The Eskimo branch of the yellow race thus teaches us one half of the vastly important truth that the conditions of human existence may be either too hard or too easy. Mankind near the Poles provides us with one illustration; mankind in the tropics, where never yet civilisation was to be found, teaches us the other. But when we consider the Eskimos, and the influence of conditions, let us beware of the modern error of attributing everything to race, as if life were not an adjustment between the organism and its conditions.

The Human Virtues Richly Represented Among the Red Indians

The North American Indians obviously partake in several respects of the characteristics of the yellow race, though the Mongolian eye is less to be found among them. The skin colour is indicated by the term "Red Indians," and we are familiar with the character of the hair and the cheekbones. Here, also, is a branch of the race which has been isolated and subjected to excessive rigour. But those who have travelled with Eskimos to the North Pole, as Peary did, and those who have acquainted themselves intimately with the Red Indian, are agreed that the most notable of human virtues are richly represented among both these peoples, and it is probable that no one has more admirably developed his senses and his intelligence for solving the practical problems of life than the Red Indian, whose observation, courage, resource, memory, and inventiveness have won innumerable tributes from travellers.

A serious responsibility devolves upon the British Empire in regard to the remnants of this remarkable people, the pioneers of mankind in the Western Hemisphere; and it is good to believe that the appalling ravages wrought by tuberculosis and alcohol in past years appear to be within reach of an end, and that, under the conditions of the present day, the number of these people is actually showing some increase. They may yet play a notable part in pushing the limits of civilisation as far north as nature will permit this to be done.

What May Happen if the Yellow Races should Eat Wheat Instead of Rice

In qualifying with modern knowledge our notions of race, we must recall the notable fact that the chief representatives of the yellow race live mainly upon rice, whereas white people live mainly upon wheat. It is certain that rice is inferior to wheat in nutritive power, and it may be more so than has until lately been supposed, seeing that minute traces of certain compounds in the wheat grain are of such high importance for human development. There seems reason to suppose that the substitution of wheat for rice in the diet of the yellow race, or the inadequacy of the world's wheat supply to feed the white race, might notably modify, in various directions, the characteristics and destiny of the two races.

In this connection it is interesting to note that the modern Japanese are adding meat and milk in large quantities, as well as wheat, to their diet. It will be of notable interest to observe the possible consequences of this modification of diet upon the supposedly *racial* characteristics of the Japanese. Students of Sir William Crookes' book on the wheat problem, and of the recent work upon the dietetics of wheat, will also be concerned to note the influence upon the Chinese race which might conceivably be exerted in the near future should Siberian wheat find Asiatic, instead of European, mouths to swallow it, as appears, from the awakening of China, to be a by no means impossible contingency.

Certainly, and in any case the yellow race taken as a whole will play one of the leading parts in the future of mankind, and the nature of that part for good or for evil, will ultimately depend upon the racial character, physical and psychical and upon the degree and direction in which it may be modified by change of diet or habit future on one ground or another even granted that their native potentialities are high but the Chinese and Japanese are too numerous and too fertile and they have too long had a civilisation with overcrowding and infectious disease and narcotic drugs of their own to fear contact with ours as so many other races have had reason to do

THE MOST NUMEROUS FAMILY OF THE MOST NUMEROUS RACE IN THE WORLD"

This photograph shows types of the Chinese people, the most numerous nation in the world, belonging to the most numerous race in the world—the yellow race. The Chinese Empire has a population of about four hundred millions, and the events of the first decade of the twentieth century suggest that this race will play an immense part in the future of civilisation

This is not a race which is slowly disappearing, it is not a scanty race, it has nothing to fear as a whole—unlike its scattered offshoots—from the devastating influence of our civilisation, with its diseases and its vices. The Tasmanian, the Australian aboriginal, the Red Indian, the Maori, and many more may be all but ignored for the There they are and there they will remain or rather, there they will not remain for they will certainly spread, and there is no sign or shadow of any power on earth that can ultimately say them nay

Evidently the problem of intercrossing has to be faced, as it has had to be faced a thousand times already in the history of

mankind. Race-prejudice, race-hatred, instinctive race-antipathy are to be allowed for, but not more than their due. No antipathy exists between, for instance, European men and Japanese women, though it is stated still to exist between European men and Chinese women. Familiarity is most potent in this sphere. The consequences of intercrossing between the white and the yellow people have to be faced.

The Effects of Intermarriage Between the White and Yellow Races

Experience hitherto is but fallacious, it is too scanty, and it has not been obtained under fair conditions. If the problems of racial intercrossing are to be solved in any fashion satisfactory to science, two primary conditions must be satisfied. They have never yet been satisfied in modern times. The nurture, including education, religion, social consideration, and opportunity, of the resulting children must be the same as that of children of single racial origin. If this condition be not satisfied, obviously the experience is vitiated as an "experiment," and nothing can be argued from it. Secondly, the intercrossing representatives of the two races in question must really be representative of their respective races; for if, say, the father be a white man who has left his country for his country's good, and, say, the mother be a yellow woman of indifferent moral character and habits, what of value as to the consequences of racial intercrossing can possibly be argued from the children? Yet such, too often, have been the kind of parents from whose children such sweeping anthropological generalisations have been inferred—parents who may be justly regarded as wholly unrepresentative of either race in question.

Science Knows Nothing Against the Joining of Two "Equal" Races

Here, since science is our object, we make no assertions, in the absence of the necessary experience; but in the name of science we repudiate such experience as cannot serve science, except to the extent of showing that children who live under a slur, or children of indifferent parents, are unlikely to turn out well. Racial intercrossing is not required to prove such propositions, and the available illustrations prove nothing as regards racial intercrossing.

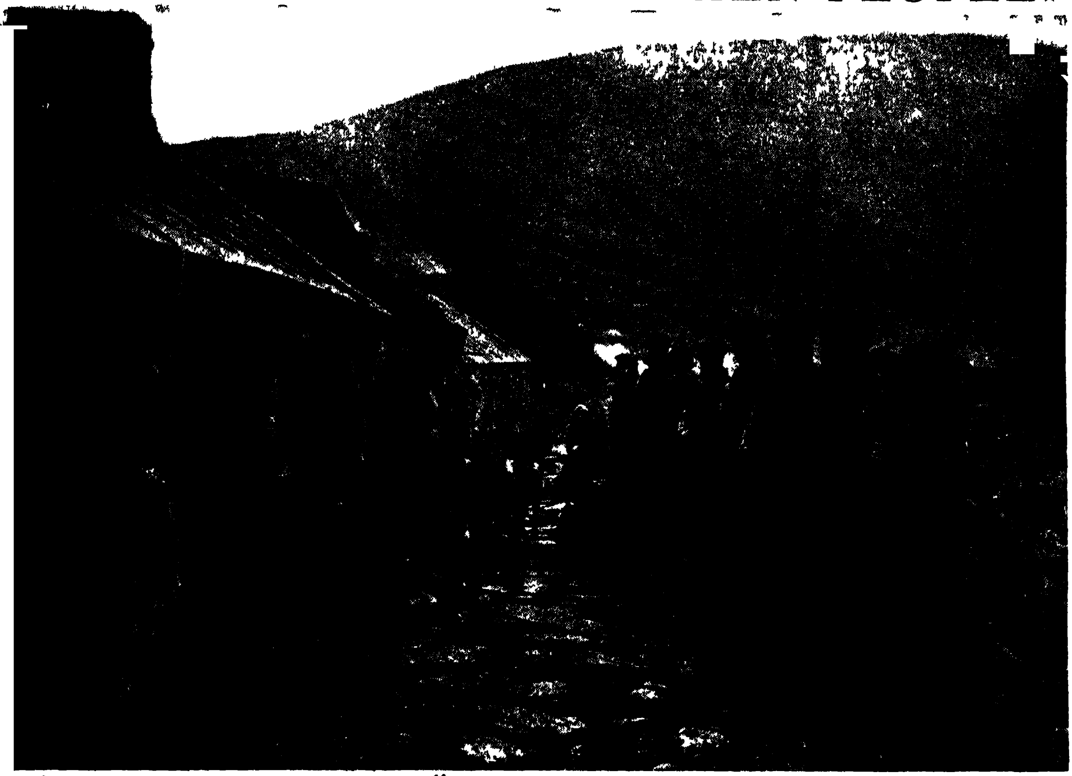
All that science can venture to assert, so far, is that, granting the natural equality of two races, nothing is known, in the scientific sense of knowing, which entitles us to expect that the children of two such races should be naturally inferior to the children of either. But the tendency of contemporary events is utterly delusive if posterity is not able to speak on this question with no uncertain voice.

The yellow race is not the only great race in Asia. The records of Indian civilisation are conclusive on the point. In Northern Asia, as we should expect from our observation of the North American Indian and the Eskimo, the conditions are too hard for greatness, or at any rate for recognisable greatness. In the southernmost portions of land commonly reckoned with Asia, the conditions are tropical—too easy, and therefore, in the long run, too difficult, for the maintenance and nurture of greatness. In intervening zones, as in Northern India, the records of philosophy and art and legislation need no qualification, even if such supremely great teachers as Buddha had not been of Indian origin. Here we have a race, or rather a great mixture and farrago of races, which is not yellow, and is not white. Its affinities, many will tell us, are European; and, indeed, men still speak of the Caucasian, Indo-European, or Aryan race, in which are included such forms as, say, the Swede and the Hindu.

How Far Does Language Go in Marking the Boundary Line of Races?

To the biologist or the modern anthropologist this is perilously near nonsense. If the word "race" is to have so wide a meaning, it has no meaning, and had better be abandoned. But the contemporary student will be left without a key to the mystery unless he realises the history of these notions.

The evidence on which most accepted ideas of the great races are founded is derived from language. Philology, or the science of language, recognises affinities between this tongue and that, and fundamental differences between both of them and a third. These differences may be profound. It is not a long step from Northern English to Dutch, but that from English or Dutch to Chinese is almost measureless. The whole genius, as we say, of the two kinds of language, the whole theory of them, their growth, structure, grammar, alphabet or absence of an alphabet, is incalculably different in the two cases. Philologists, notably represented by the late Professor Max Müller, pursue this fascinating science, which may well claim the highest importance, dealing as it does with man in his all but highest and most characteristic attribute. In doing so, they incline to argue from language to race. They group, classify, compare, and



“ HE PARLIAMENT OF ST. KILDA”—PRIMITIVE INHABITANTS OF THE BRITISH ISLES

A FAMILY IN LAPLAND, SHOWING HOW A MOTHER CARRIES HER BABY

All men, of course, belong to one species, but within its limits we certainly find various races. is no doubt about this if we compare such types as are shown in these two pictures.

contrast languages, assume a correspondence in race, and a similar or single racial origin for two sets of people, each of whom have the same type of language, or use the same, or practically the same, words.

We can all see that there must be something in this. Evidently the similarity between older forms of English and Dutch goes with the largely common origin of the peoples in question, and so on. The question with such a theory, however, is how far it goes. And this question is answered by modern anthropology with no uncertain voice.

Evidently such a theory as this of the philologists cannot be of constant application. Languages are adopted, languages are imposed, convenient forms replace inconvenient forms, conquerors insist on the substitution of one tongue for another, and then, perhaps, disappear, while the alien language remains, seemingly native to the race upon which it had been imposed. Further, men are men, and a brown man in India and a white man in England may put notions together similarly in similar circumstances, without its following that they both belong to the Indo-European race, or that there is any such race.

The People of India who are Nearer to the White Race than Yellow People Are

It is certain, in a word, that the philologists carried their theory too far; and that is one of the reasons why, with advancing knowledge, we are so much less certain about matters of race than men were a generation ago, when all that was needed was to compare language, and the questions of race settled themselves. All homage, nevertheless, to philology, past and present, and to its future services, even though we expect these to teach us more about the human mind, and less about racial types of body, than used to be supposed.

Let it suffice, then, that many brown people inhabit India and its neighbourhood, that they are on the whole nearer to us in many ways than are yellow people, and that they number great "races" as well as primitive. Here, again, we may observe that *pure* and *primitive* races are those which are isolated. The most primitive people in the world, or almost the most primitive, even more so than the Ainos, are the aboriginal inhabitants of the hill country of Ceylon, who are called the Veddahs. Indeed, it is difficult to speak of them otherwise than in such terms of pitying contempt as the more humane of the Roman authors used when describing the isolated islanders whom they encountered on our own southern shores.

Wandering about the earth, having no native land, we find a strongly marked kind of people, not even to be included in the most comprehensive term of "Indo-European," whom we call the Jews. They may be of any colour, perhaps because they have lived for so many ages in every kind of climate. In the South they are tanned and coloured by the sun, and thereby protected from its rays, just like their neighbours; whereas in the North they are often quite fair. That they are definitely an Oriental race, we may agree.

The Great Race of People Without a Native Land

The reservation must be made that all races are ultimately Oriental—man was not born in Europe. But the Jews are more recently Oriental than the contemporary Europeans, among whom so many of them dwell. They demand brief mention here on many important grounds.

The Jewish race is peculiar because of its ubiquity, its strongly marked racial characters, its number amounting to perhaps no more than ten or twelve millions to-day—yet was never so numerous as to-day—and its unquestionable claims to moral and intellectual greatness. Conspicuous in no art save music—though the modern painter Israels is an exception—and deficient in many qualities which are or may be made admirable, and notably in those which show themselves in great political achievement, and in war, and in the mastery of Nature, the Jews are nevertheless pre-eminent in other directions, having given us the noblest monument of ancient literature, and having provided modern civilisation with its dominant religion and practically the whole of its canons of morals, above all, of social and domestic morals.

Will the Future Witness the Disappearance of the Racial Identity of the Jew?

Conspicuous in Jewish practice has been the avoidance of intermarriage with other peoples. For good or for evil, this has undoubtedly been the cause of their unique racial purity of to-day, with its pleasant and unpleasant, admirable and less admirable features. They have been in the Gentile world, but not of it. They have made all manner of terms with their conquerors, have accepted indignity, servitude, ignominy, exclusion from all manner of pursuits and possibilities, everything but the degradation of their women; and they have kept their blood pure. If man at large did not require

every line of space that can be spared for his consideration, more might well be said about this race, in speaking of which even the modern anthropologist can scarcely feel that he is describing a fiction. It only remains to be added that the most recent authority, Dr. Maurice Fishberg, reports the gradual breaking down, in such great centres as New York, of the Jewish prejudice or canon against intermarriage. All modern influence works in this direction; and the future may witness the disappearance, as a racial identity, of this remarkable people, if it should not happen that the Zionist gives them a country of their own, and permits their independent development there.

The great branch of mankind which we call the white race remains to be considered. We describe it by its colour, though that involves many difficulties. If we attempt any other definition of the races of man, we find, however, that the difficulties are at least as great, and it is therefore probable that the "colour-line" will long remain the best defined between races of man, even though the case of the best marked of all races, the Jews, who may be blue-eyed and fair-haired, or very nearly black, shows how little that line is ultimately worth.

The white peoples of the earth inhabit its temperate climes—an incalculable advantage for their development, as we have already argued. Relatively they are, of course, white, though wide variations are to be found between, say, Swede and Sicilian, even allowing for the possible negro admixture in the latter. But it is to be noted that the white peoples are not really white—that is to say, the skin is not colourless. Only abnormal and morbid specimens of mankind, called albinos, are really white. The colour of the white race is to be found not merely in the iris of the eye, but also in the upper eyelids and in other parts of the body much less exposed. In all parts of the body, exposure to certain constituent rays of sunlight will excite the pigment cells of the skin; and in many Anglo-Indians the exposed skin may be as dark as that of many natives. Within the limits of the

PRIMITIVE INHABITANTS OF THE BRITISH ISLES—PEASANTS OF THE WEST OF IRELAND

The great races of mankind, such as our own Anglo-Saxon race, are not pure single races, but blends of several. The nearest approach to a pure race in the British Isles is to be found, perhaps, among the inhabitants of the Outer Hebrides or the West of Ireland.

white race it is therefore not unnatural to find at least two well-marked varieties, distinguished by their degree of colouring-matter, whom we call blonde and brunette. This division raises many interesting questions, for students report that the blonds do not withstand well the processes and risks of civilisation, and that, on the whole, they are dying out and being replaced by the brunette or darker type. If it should prove that the blonds have characters of mind which are more or less their own, and which have a permanent value, this alleged decadence of the type is much to be regretted on other grounds than that of their undoubted beauty in many instances.

There is substantial ground for the argument that it takes a race a long while to become tolerant of the artificial set of conditions which we call civilisation. The Jews are the only known example of a race which can survive civilisation in the strict sense. The Chinese can do so, but with what necessity for incessant replenishment of urban by rural blood we cannot say. In Europe, the Jews apart, the rule seems to be that the cities consume what the country produces, not only in the way of food, but also in the way of men. According to some recent observations, this destructive process seems to tell more hardly upon the blonds, who are on the whole the descendants of the more northern peoples, whose acquaintance with cities and their conditions is more recent than that of the darker dwellers near the Mediterranean. Some such explanation might be advanced to account for the asserted disappearance of the blonds in modern civilisation.

At any rate, the white race remains, though it may thus tend in the future to consist of its browner representatives. Its characteristics need no special description, for our description of other races usually implies a description of ourselves as not peculiar in such and such other respects. The white race, if we include therewith such Orientals, all originally dark, as the Jews and the ancient Greeks, have made the modern world, and it remains to be seen to what extent they will be sole arbiters of its future. The succeeding sections of our study will normally deal with this race simply because it is the race whose members have been chiefly, almost exclusively, studied, alike as regards the skeleton or the muscles, the senses or the intelligence. A vast field remains for work in studying the various races of mankind, primitive and great, with as much detail and thoroughness as in the case of the modern

THE ESKIMOS—A TRAGIC EXAMPLE OF A PEOPLE HELD BACK BY ISOLATION

The Eskimos, who are an offshoot of the yellow race, but are living among the rigours of the Arctic regions, are a striking and tragic example of the fact that the isolation of a people hinders its development and progress.

THE RED INDIAN AT HOME—CUT OFF FROM THE GREAT BODY OF THE RACE IN ASIA

The Red Indians, who belong to the great yellow race and have been the pioneers of mankind in the Western Hemisphere, have been greatly hindered in their development by being isolated from the great body of their race

European. Man cannot be too carefully studied in all his forms, numerous and rare, pure and mixed, simple and complex.

Hereafter we study man in general, referring scarcely at all either to racial or to individual differences. We have said enough, however, to show that the racial differences exist, and it must never be forgotten that the individual differences exist also. It is certain that within the limits of any race we find much greater differences in such essentials as intimate brain structure than exist between average types of different races. This proposition clearly involves the necessity of recognising that we require a more detailed study of individual men than ever before. As we argue less and less confidently about race, and even become doubters as to the worth of racial studies which simply mass men together and take the average of them, we become more concerned to study individual men and women, of all races, at all ages, and under all conditions, realising the amazing variety of our kind. The old method of studying many specimens in some particulars, and taking the average of them, has broken down. The cruder statistical methods, and the more refined ones, termed biometry, produce results which do not withstand the criticism which study of the individual involves; and the advance of Mendelism has taught us, as never before, the futility of arguing about races until we know more about individuals.

These considerations are earnestly impressed upon the reader, by way of caution and disclaimer, before we start to speak in detail of "man" as if men were all as "like as two peas" were supposed to be until Mendel found them to be quite different.

THE DRAUGHT THAT DOES NOBODY HARM

The motor-car is killing the foolish notion that a draught of air is a dangerous thing. On the whole, there is no doubt draughts do much more good than harm, though a draught coming through a narrow space, concentrating the rush of air in a single streak, may well be harmful. Such draughts as are experienced regularly in motor-cars are perfectly harmless.

A GOLDEN RULE OF HEALTH

Why We Must Breathe Through the Nose and Why We need not be Afraid of a Good Draught

SHUT YOUR MOUTH AND SAVE YOUR LIFE

The policy of the open window is good; the policy of the open door is better, but the policy of the closed mouth is best. Of all aspects of health this is the chief.

The first of all health proverbs is—Shut your mouth and save your life. Unless you have something to say or to swallow—and very often even then—your mouth is best shut. The breath of man was planted in its nostrils, and there it should remain.

The health of children is far too important a matter to be ignored or dealt with incidentally, and we shall do it some justice later. But meanwhile, unless we are to leave undone our duty in dealing with the problems of air and health, we must discuss the case of those who cannot breathe freely through their noses and who therefore cannot obey the first law of health. This question has now reached such huge and unprecedented proportions in this country, affecting such a large percentage of the population in a respect which is radical for health, that it requires immediate attention. The seeds of the mischief are laid in early years, as are the seeds of most mischief, and their origin is at present obscure.

At any rate, a large percentage of all our city populations—about eight per cent according to the new figures—now suffer from adenoids and the consequences of adenoids. The recent medical inspection of school children has justified those observers who had declared that this was a great national evil, and that it was affecting more and more school children. Though adenoids are found in all parts of the country and the town, they seem to be specially associated with city life, and have for many years been noted as one of the special liabilities of the Jews, who are an urban people. It seems, however, that English children now suffer as much from adenoids as Jewish children, and the music-hall version of the Jew, which almost always depicts him as speaking in the fashion of people with obstructed noses, will soon lose its point. The immediately existing cause of the complaint is probably dust—and may prove to be dust of a special kind, containing special microbes. This dust, as a rule, causes colds in infancy and very early childhood which lead to the morbid overgrowth of tissue at the back of the nose and throat which we call adenoids.

The experts in this subject distinguish between adenoid growths at the sides of the nose, which interfere with the hearing, and "central adenoids," which interfere with breathing. These are the commonest form, and these alone concern us here. They are the chief cause of inability to breathe through the nose. To them must be added a very common defect of the nose, which consists in a displacement or deflection of the partition between the two nostrils. This means that one nostril is largely obstructed, and the deflected partition usually provides, at some kink or other, an admirable breeding-ground for microbes.

Children with adenoids, or with a deflected nasal partition, are exceedingly liable to colds, which make their breathing all the worse, and in the course of a few years these colds do further injury to the lining of the nose, and not least to certain parts which have the special duty of purifying the air as it passes through. The state of these people thus goes slowly from bad to worse. They become more and more liable to colds, sore throats, attacks of laryngitis and bronchitis, and many of them begin to get wheezy in their chests, and show signs of asthma. Some of them also, especially those who live in the

country, become very liable to hay fever. All these points have to be added to the bare fact, which is serious enough in itself, that they are largely or even wholly compelled to breathe through their mouths.

The mouth has therefore to be kept open, giving a foolish and weak appearance to the face. This appearance of stupidity is reinforced and justified by the child's mind. It is not getting sufficient air into its blood, and—far more important, though forgotten by most people—the child is being constantly poisoned by the microbes which settle in its nose, and by those it breathes through its unguarded mouth.

The Breathing Through the Mouth which Vitiates and Stunts a Child

Adenoids may disappear as the child grows older, and parents will often hopefully wait for this to happen while the child is being half suffocated and half poisoned all the time, and while its growth is being stunted, and its development vitiated for life. The general rule is that the adenoids do *not* disappear; and as for the troubles due to a misshapen nasal partition, they are cumulative and uncontrollable so long as that partition remains where it is.

Every doctor knows a "mouth-breather," and what the future history of that mouth-breather tends to be. But only the experts yet know that this condition of mouth-breathing, due to nasal obstruction and the presence in the nose of disease which converts what should be a filter for microbes into a breeding-ground for microbes, is one of the chief predisposing causes, as we might well believe, of infection by the microbe of consumption. That, however, is almost certainly the fact, and the time is very near at hand when, as a nation, we shall deal with it as we should.

The Great Harm that May be Done to Children by the Prejudice Against Surgery

Modern surgery can remove adenoids with the utmost speed, ease, safety, completeness, and comfort. It can nowadays even deal radically with defects of the nasal partition, though this involves a substantial operation and a fortnight's "holiday" for the patient. The present writer speaks from personal experience of both operations on himself, and the former upon his own child; and he writes with the utmost conviction, and anxiety to breed conviction in others, when he says that no one should nowadays permit the continuance of nasal obstruction in himself or in anyone for whom he is responsible.

Surgery alone is the remedy for these conditions, and for all the evils which flow therefrom. Nasal douches are not valueless, but they can do nothing radical. The various advertised remedies which profess to cure nasal obstruction without operation are all but valueless. They can do, at the utmost, what douching with an innocent antiseptic does; but the experience of those who know is clear and unequivocal that surgery is the best remedy for all these cases, and a very splendid, effective, and beneficent remedy it is. It is probable that in no respect does the popular prejudice against surgery, and fear of even the simplest and most trifling operations, do more harm than in its interference with the performance of the simple operation for the removal of adenoids from children's throats.

Now we may amplify our dogma, and say that the very first condition of perfect health is to breathe through a healthy nose. Allowing for heredity and its decrees, we may fairly say that this is beginning as near the beginning as the individual can. To say "Shut your mouth and save your life" is all very well, but what if one cannot breathe except through the mouth, or what if the nose be a veritable Eden for microbes? First, one must breathe through the nose; second, the nose must be healthy.

The Reason Why We Should Breathe Slowly Through the Nose

One must breathe through the nose because it moistens, warms, filters, and even to some extent sterilises the air. The mouth can do none of these things, all of which are important, and some of which are absolutely essential. The nose exists for these purposes. Life is intensely economical, and constantly employs one structure for as many purposes as possible. If to admit air freely were the whole requirement, we should use our mouths for that purpose, and we should not possess noses. It is not the whole requirement; indeed, to have too free and clear a nose is almost as bad as to have an obstructed nose. If the air be not compelled to pass slowly enough through the nose, it will not gather enough moisture, nor be sufficiently filtered of dust and microbes; and the tonsils—which are auxiliary to the nose—will probably prove inadequate to protect the voice-box, the windpipe, and the lungs from the effects of dust and infection. We see people using respirators, and we hear of the filtration of the air which enters modern theatres or club-rooms. But everyone carries with him, if he be in health,

an efficient respirator and filter, which he must continue to use at his peril.

We said that not only must we breathe through the nose, but the nose must be healthy. People sometimes filter their water at home, and in a little while, owing to neglect and misunderstanding of the problem, the filter that was becomes a trap and nursery for microbes, with the motto "All welcome" visibly inscribed upon its iridescent surface for all eyes that can read it. Just so with the nose. If it gets out of order it encourages infection, which leads to its own degeneracy, and later to the infection of still more important and vital organs. No child or adult with an unhealthy nose is safe, and the time is at hand when no insurance office will accept any risk in such cases.

So much for this most important subject, and now we shall see that it has prepared us for the study of a new subject, which we could never have understood if we had not dealt first with the nose. That new subject is the too familiar one of "catching cold," and the whole question of draughts and protection from them. Now, we must understand, once and for all, that a common cold is an infectious disease, due to particular kinds of microbes, just as definitely as plague is, or cholera or mumps.

The Serious Infectious Disease that We Call a Common Cold

The healthy nose very rarely contracts this particular infection, just as the healthy stomach very rarely, or never, contracts infection by microbes that attack it. The healthy stomach produces a powerful antiseptic, hydrochloric acid, which kills microbes. The healthy nose produces a mucus which is also definitely, though not highly, antiseptic; and, further, all parts of the healthy nose are perfectly *drained*, and there are no odd corners where the mucus stagnates, and in which microbes can multiply. The best way in which to avoid the disease we call a cold is therefore to have a healthy nose; and if one has not a healthy nose, no precautions will prevent one from contracting colds, and possibly maladies far worse than colds.

It may be argued that, if the nose runs these risks, it would be better to breathe through the mouth. Not at all. Microbes and dust instantly strike the back of the throat, which is continuous with the back of the nose, and in all other respects one is worse off than before. There is no remedy but to acquire a healthy nose, and then to breathe through it.

But, of course, there are limits to the resistance of any vital organ, and we must not suppose that our duty, as regards colds, ends here. Anyone may meet particularly virulent microbes of certain kinds, and acquire a cold, just as anyone may meet particularly virulent microbes of other kinds, and acquire cholera or leprosy. Here, as in all other cases, our duty is twofold—to protect ourselves against infection, and to avoid it.

The Hidden Perils that Face Us in our Daily Lives

Now, where is the infection of colds to be found? For instance, comparing the inside of a tramcar or 'bus to the outside, where is the infection most likely to have been deposited, and where is it most likely to remain? Once the question has been raised in this form, no one can hesitate as to the answer. It is one more illustration of the truth of Bacon's dictum that philosophy and science mainly consist in teaching men how rightly to put the question to Nature. If we think of "catching cold," then we shall vote for the inside of the tramcar as safest; if we think of avoiding the microbes, we shall vote for the outside of the tramcar as safest. Our answer entirely depends on how we put the question.

To the man who has studied these matters, dust, dirt, and darkness are the enemies; and they are tenfold more to be feared when one knows that people with colds have coughed, spat, sneezed, cleared their throats, exposed their handkerchiefs, and so forth—it is an unpleasing but inevitable catalogue—in the area which he is now invited to occupy. He finds it very uninviting, and takes his place on the roof, in winter as well as in summer. If we think of microbes as real and palpable, as we think of mad dogs, or fleas or wasps, or any other form of visible life that we object to, we shall very soon see the way of safety, which, in this case, is the staircase to the top.

The Ills that Flesh is Heir to when Weakened by "Cold"

Of course, this is not the whole story. Whatever a "cold" may be, there is such a thing as cold, and its devitalising effect is beyond question. Pasteur took a fowl, an animal which is normally immune to inoculation by the microbes of anthrax, and stood it with its feet in cold water. Thereafter the fowl was found to be susceptible to inoculation. Its immunity had broken down under the influence of cold. So there is something in the theory of "catching cold," after all.

Quite so, but we must be sure that we understand what that something is. People sometimes read this experiment as if it proved that its cold feet had given the fowl anthrax. Not a bit of it. What gave the fowl anthrax were the bacilli of anthrax, to which the cold had rendered it susceptible; but a fowl or a sheep might have its feet in cold water for all time without contracting anthrax, or any other infectious disease, if the infective agent were not present.

Is it True that We Cannot Catch Cold from Sea-water?

And now we can interpret the well-known fact that "people don't catch colds from sea-water." It is true that we go to the seaside, and bathe and shiver while we dress, or paddle, or even get our feet wet through our shoes and stockings, and get caught in showers, and splashed with spray—and don't "catch cold." This should be enough to prove that there is more here than we have understood. The real explanation is simple enough. Even though we have been in the water too long, and have really lowered our vitality, just like Pasteur's fowl, we don't catch cold because the experiment is not completed—the inoculation is not made. There are very few germs of a cold at the seaside; none at all on the beach, and very few in the houses, as a rule, and we are out of doors most of the time. So we no more catch cold than we catch hydrophobia in the absence of mad dogs. Moreover, as a rule, our exposure to sea-water is not severe enough to devitalise us, but proves to be a tonic, and even if we did encounter the germs of a cold we should be fitter to resist them. And it may be added that the salt in sea-water when we bathe or paddle is a stimulant to the skin, and helps our health, just as the motion of open air helps our health by giving a kind of tonic "fillip" to the skin. But beyond question the chief and sufficient explanation why exposure to cold sea-water, even over-exposure, as when we bathe too long, does not give us colds is that the germs of the colds are usually not there.

Why We Often Catch Cold on Coming Home from the Seaside

One unfortunate fact may be added about sea air or country air for the city dweller. It is very often noticed that, though we enjoyed our holidays, got wet through, and exposed ourselves over and over again, and caught no harm, when we get back to town we promptly catch severe colds. The fact is only too familiar to many people. Apparently the pure air was too pure—in the sense that we lost our faculty of resistance to dust and its contents, simply by lack of practice. When we get back to the city streets, and our noses are filled with dust and microbes again, after an interval they are very apt to succumb, which seems rather hard lines, but yet is quite understandable. It may often be, also, that we return home, only to be attacked by germs which have been multiplying there in our absence—unless we were uncommonly wise in having our house properly cleansed and aerated and illuminated by the sun in our absence. Of course, if we exclude air and sunlight, and stop dusting and sweeping, we must expect to find something lively and deadly lying in wait for our return.

As for street dust, with its abominable and offensive contents, undoubtedly the disappearance of the horse will do much for its improvement in coming years. It is a public nuisance and a private danger in many ways. In the streets it is dangerous to the throat and nose and eyes; and, indeed, we should do well, on these grounds, to transfer to "street air" the undeserved odium hitherto cast on "night air."

The Germs of Disease that are Allowed to Float About in Cities

The best thing about the night air of cities is that it is less "streety" than day air. But city dust is not objectionable in the streets alone. It sadly compromises the policy of the open window by making that policy involve the reception, along with fresh air, of quantities of dust and dirt, and microbes and smuts, which vitiate the air, make everything dirty, clothes and curtains, and books and all. It is certain that, in a short time, popular opinion will be sufficiently educated in these matters to demand that streets shall be kept cleaner and less dusty than heretofore.

Meanwhile, the policy of the closed mouth is more urgent than ever. The more dirty and dusty and microbic the air, the more essential is the filtration which the nose alone can effect for us. At times, in the streets, we may encounter unpleasant odours, which tempt us to hold our noses and breathe through our mouths instead. This is quite a mistake. The smell is indeed a warning, and should be acted upon, but by getting away from it, not by exposing ourselves far more gravely to the infection that accompanies it, which is what the rash policy of the open mouth amounts to.

The most fearful of all microbes in this country is the tubercle bacillus, the cause of consumption. Wise fear of this germ

enforces, more than all other considerations, the policy of the closed mouth. At present, consumption is hideously neglected in this country, as everyone would admit if the disease commonly killed in seven hours or days instead of years; and the consequence is that its microbes are very frequently encountered by probably every one of us.

The Words of the Wise King—He that Keepeth His Mouth Keepeth His Life

We meet them in the open street, to some extent, but far more in railway carriages, trams and 'buses, public-houses, music-halls, and in all other places where men spit. Until this most deadly of all diseases is abolished, as can be done at any time, and will probably be done within twenty years, the wise citizen will keep the door of his mouth more closely than ever, reinforcing with the science of Pasteur and Koch the words of the wise king: "He that keepeth his mouth keepeth his life!"

It is right, in considering the policy of the open window, that we should know the truth about draughts, and, on the whole, there can be no doubt that draughts do immeasurably more good than harm. We should remember that the injury done by a draught depends upon its local intensity. It follows that to open the window six inches may be risky, but to open it as far as it will go may be safe. The safe way, and the comfortable way, in which to practise the doctrine of the open window is to make one's room, as far as possible, part of the open air. Instead, we try to compromise; and though entire exposure to the open air would have done us good, we suffer from admitting a narrow streak, which is in the form of an acute draught. It is the difference between a sea bathe and being played on with a fire-hose.

The hygienist may really hope, however, that his arguments will soon be rendered superfluous by the motor-car. Private cars and taxis and motor-'buses are uniting to teach all sections of the population that their ideas about draughts and colds, and their fear of the open air, even in the form of intense— but *broad and copious*— draughts produced by motoring, were ill founded.

Why Plants are Good in a Room by Day but Bad by Night

The action of plants upon the air cannot be entirely neglected by the hygienist. During the daylight, green plants absorb carbonic acid gas from the air, and give out oxygen. They therefore directly ventilate the air, though in exceedingly small degree. At night, however, the state of things is reversed. At night the plants no longer decompose carbonic acid, but merely breathe, using up oxygen and producing carbonic acid. Plants are therefore desirable in living-rooms, and by day in the bedrooms of the ill, but they should be removed from bedrooms at night.

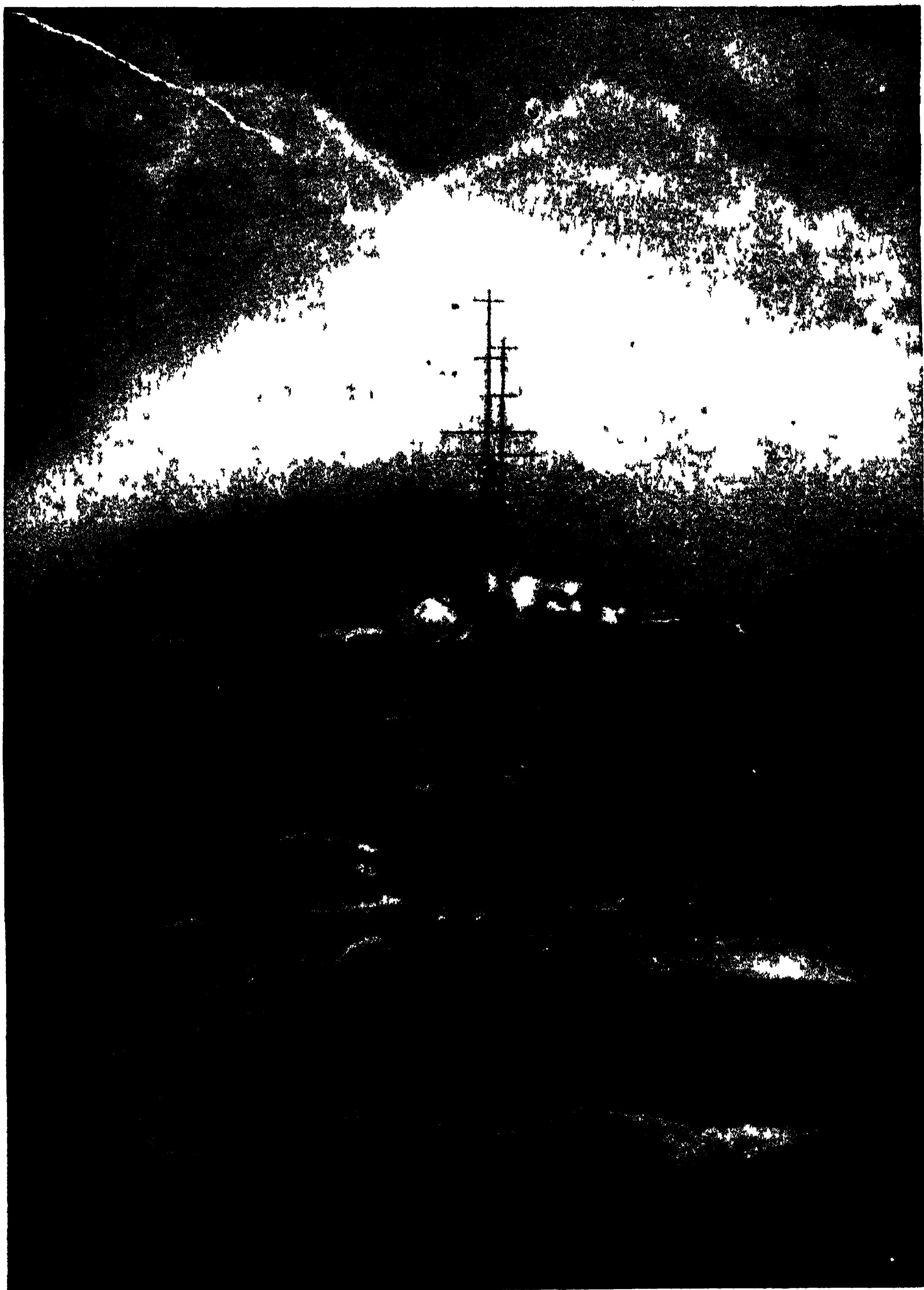
What has been said about dust will suffice to prove that rooms should not be dusted or swept in the ordinary way, but with the aid of damp tea-leaves, or a vacuum-cleaner, or a carpet-sweeper, or in any fashion whatever, provided that no dust be raised. In a few years we shall marvel at the fashion in which we used to clean our rooms. And similarly all the sweeping of city streets should be preceded by the use of water. Ten years ago, in Edinburgh, one of the greatest medical schools in the world, the streets were dry-swept every night, raising huge clouds of dust, which could be seen knocking for admission at—commonly closed—windows of even second and third storeys. If there be any city where streets are now swept in this fashion, it should be made known as a town unfit for human habitation.

The questions of weather and climate are, of course, connected with the problem of air, but they introduce so many other considerations that they require to be dealt with separately. But there is one important point to which we must make final reference.

How We may Get Used to the Dust of the Town and Adapt Ourselves to it

This point is the great fact of adaptation and its laws. We have already hinted that one may become unaccustomed to city air and dust, so that, on return from an excellent holiday, one may yet be knocked down by a "cold." There is no doubt that we can and do acquire a great deal of adaptation and resistance to atmospheres which are short, often far too short, of perfect. The case of the patient from the open air, who found the air of an admirably ventilated ward almost intolerable, is really a typical one. This adaptation works in all directions, and if it is to be successfully carried out it must be sufficiently gradual. The convinced and enthusiastic reader is urged to adopt the policies of the open window and the open door and the 'bus-top as thoroughly as possible, but he should do so gradually.

As for the supposed adaptation of the slum populations of our cities to the slums, and the breeding of a slum race to which slums do no harm, it will be time to discuss that when we find the race to which slums do no harm; and the hygienist is inclined to wish for a few concentrated samples to silence those who apologise for what is so immeasurably beyond apology.



The modern battleship is a floating raft of steel, on which are placed the most terrible instruments of force that science can devise. Built of water-tight boxes of steel, and armoured with 12 inch steel plates, a battleship is designed to survive the explosion of a torpedo, and can pour out of her big guns a shower of half-ton shells. The next battle, if fought on a clear day, will scarcely last fifteen minutes

WHAT A BATTLESHIP CAN DO

The Most Terrible Concentration of Power Achieved by Man Since the Beginning of the World

WRECKING A TOWN AT 20 MILES IN 40 SECONDS

NOTHING is plainer or simpler to look at, and few things even in modern civilisation are uglier, than a battleship. It is a raft built up of steel plates, and raised high out of the water; less than two hundred yards long, barely thirty yards in breadth, and narrowing at the end. On the top of the raft are ten guns, set in pairs along the centre line, and over each pair is a low protective dome of metal. Only the protruding muzzles of the guns can be seen. There is little else to arrest the attention, except two dwarf funnels like truncated factory chimneys, and a structure formed of two huge steel pipes, resembling a half-made crane, and serving apparently as a mast.

The modern battleship is not a thing of beauty or grandeur. Her lines are hard and harsh; her colour drab and insignificant; even in size she is not remarkable.

Warships twenty years ago carried heavier guns than hers, and the vast Atlantic liners show more majestic as well as far more picturesque. A battleship like the Orion or Monarch is really a small movable fort—a floating machine designed to carry ten large pieces of ordnance. Her highest speed is about twenty-six miles an hour, and there are many warships and merchant ships which can move faster than this. When going into battle she will be stripped of her mast, and show plainer and uglier than ever—a low, grey hulk, with no sign of life visible on it, looking like the dismantled wreck of some tramp steamer.

But into this sombre battleship has gone all that modern science, modern invention, and modern industry can devise for the purpose for which she is built. The most tremendous moving engine of destruction that mortal brain and hand has made, she stands for power incarnate—power stripped of all its show and pageantry, so that nothing shall interfere with its terrible effectiveness. The most powerful of steam hammers exerts a force of about 500 foot-tons. H.M.S. Orion, with her great 13½-inch guns alone, can produce every two minutes a muzzle energy of 700,000 foot-tons —enough to raise thirty Orions a foot high.

By means of this enormous power she is able to throw at every broadside more than five and a half tons of hardened steel and lyddite—the most terrible explosive known. Each shell weighs 1250 pounds; ten of these shells can be fired simultaneously, and the force of the discharge carries them, at a high elevation, twenty-one miles. In full view of Dover harbour, the Orion could wreck Calais with a single broadside, and within the next few minutes she could steam out and destroy Boulogne. One broadside gun-fire of the Orion will produce something like an earthquake and a volcano combined. First will come the ten shells, delivered with the smashing force of 700,000 foot-tons; then the lyddite in the shells, amounting to about 850 pounds, will break up the steel into murderous fragments and belch out a poisonous gas.

This tornado of destructive energy, however, is produced at a great cost. The ten great guns of the Orion have a very short life, for they are rapidly injured by the force which they create. If the Orion ever fought continuously for about three hours and twenty minutes, working her ordnance as quickly as possible, she would throw 558 tons of steel and lyddite, with a muzzle energy of about seventy million foot-tons. Probably her deck of thick, hard cemented steel would then be bent and crumpled by the continual blast and concussion of the ten great guns, and the guns themselves would be useless and silent. The rifling of their inner tubes would be worn away by the cordite used to create the seventy million foot-tons of propellant power.

This is what happened to the great guns used in the Japanese warships in the sea-fights with the Russians. The bores of the 12-inch guns were quickly worn away, and the shells they fired could be seen turning somersaults in the air. The result was that the battle of Tsushima—the Trafalgar of the Russian-Japanese struggle—was won by the straighter fire of the lighter guns. For this reason the capital ships of nearly all the great navies now have a secondary armament of lighter ordnance. For instance, the new Japanese Dreadnought, the Aki, has four 12-inch guns, twelve 10-inch guns, and twelve 6-inch guns, while the Orion relies wholly upon her ten 13½-inch guns. The British battleship has, it is true, some small 4-inch guns, but they are designed only to beat off torpedo craft.

The New Principle on which the All-Big-Gun Battleship is Built

The idea underlying our warship construction is that of specialisation. Each ship is planned only as a part of a battle unit. The utmost destructive force which can be concentrated in comparatively small room is put on to the capital ship; she is allowed no secondary armament. By doing away with the smaller guns a great saving of buoyancy and space is effected; and all that is saved in this manner is spent on thicker, heavier armour, on more guns of the largest sort, and on machinery for driving the vessel at the highest speed.

Such is the scheme of the English type of Dreadnought, of which the Orion is the latest development. All the secondary armament is sacrificed, and the ship is made into a steel raft for carrying a small number of short-lived but terrifically powerful guns. Her high rate of speed, it is reckoned, will enable her to keep her opponents at such a distance that their shorter range secondary guns will never come into play. Only the heavy ordnance, in which she holds a commanding advantage, will count, and that is why she is a Dreadnought—a fear-nothing.

The Mighty Warships that Out-speed the Fastest Liners

Sometimes the number of her guns is reduced from ten to eight, and the additional buoyancy obtained in this manner is used to increase the power of her engines. In this way the cruising Dreadnought is created, of which H.M.S. Lion is a magnificent example. The Lion has only eight 13½-inch guns, as compared with the Orion's ten, but she is the fastest ship of her size in the world. She is now approaching completion at Devonport Dockyard; and Germany at present holds the advantage with her battle cruiser Moltke, with a speed of about 32 miles an hour. The Lion, however, will be able to make about 33½ miles an hour.

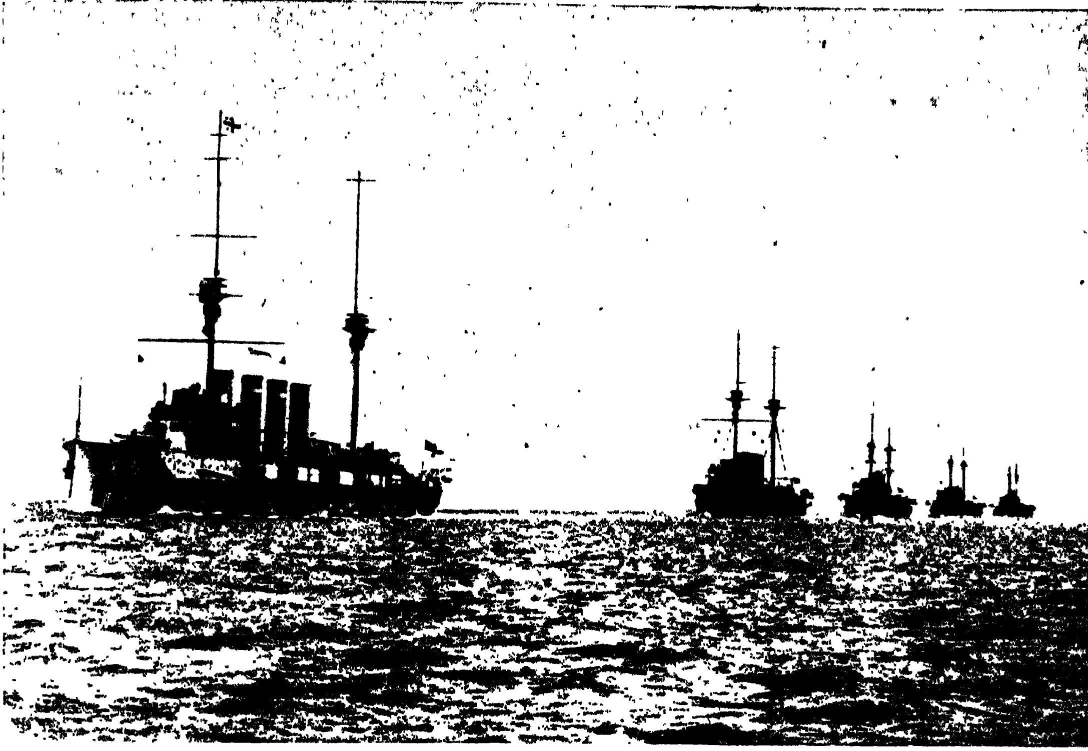
In other respects the Lion resembles the Orion. She has no secondary armament, but only very heavy armour, and a few very heavy guns. Part of the work of scouting for the slower and more powerful battleships will fall on her; and, as a rule, the two vessels will only fight ships of the same class as themselves. They form the centre of the battle unit, and their action will be mainly offensive. They will force the pace of a naval battle. Steaming broadside-on, with all their turrets swung round against the enemy's ships, they will pour together eighteen shells into them every two minutes, and in a very short time the contest will be over. Within a radius of five miles the Orion will not let anything live on a clear day. Her 1250-pound shells are expected to drill through the hardest and thickest armour. As the shell penetrates clean through the armour, the fuse connected with the charge of lyddite in the shell is fired, and so there takes place inside the stricken ship an explosion of shell and poisonous gas far worse than the explosion of an ordinary gun-cotton torpedo.

Why the Big, Quick Naval Gun has Vanquished the Torpedo

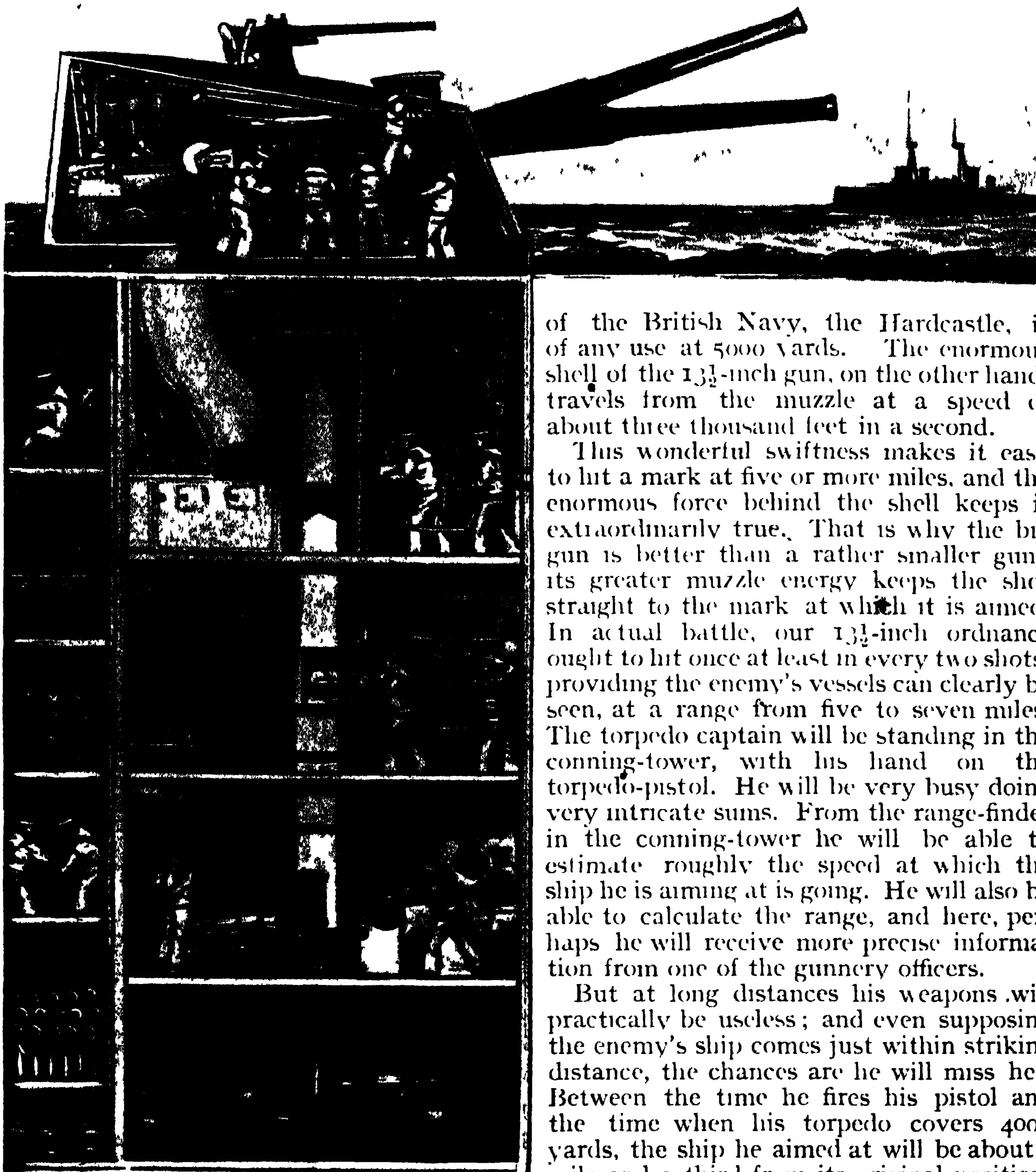
In the meantime, the battleship which is spreading death and destruction among the large ships of the enemy has to defend herself against destroyers and smaller torpedo craft. As a matter of fact, she is practically defenceless; and it is here that the idea of the battle unit is fully seen. The secondary armament has been transferred from the Dreadnought to a little fleet of ocean-going destroyers of very high speed. Thrown out in a fan before the great battleship, they protect her from the attack of torpedo craft, and do the scouting and defensive work. In short, the British Navy is now divided into an offensive section and a protective section. The all-big-gun battleship is the striking force; she pounds the enemy into a sinking wreck, while the destroyers shield her from hostile craft.

As things now stand, the big ship with the big gun has vanquished the torpedo. She is so quick that even the submarine cannot get sufficiently close to hurt her. In fighting a ship of her own class she relies chiefly on her tremendous gun-fire. A torpedo takes about ninety seconds to cover 2000 yards, and it is doubtful if even the new secret torpedo

THE MODERN ARMADA OF ENGLAND



In this picture is seen a cruiser squadron steaming in single line, ready to fire a broadside. The cruisers act as scouts for the big battleships, such as H.M.S. Neptune, which is seen in the bottom picture, leading the Home Fleet. Such an armada as this patrols the home waters night and day, ready for war, and is controlled by wireless telegraphy from the Admiralty.



THE DEPTHS OF A SHIP BELOW A BIG GUN

It is, of course, impossible to keep the ammunition for the big gun in the turret, and this drawing of a section in the depths of a battleship shows how the ammunition is stored and sent up to the turret by lifts.

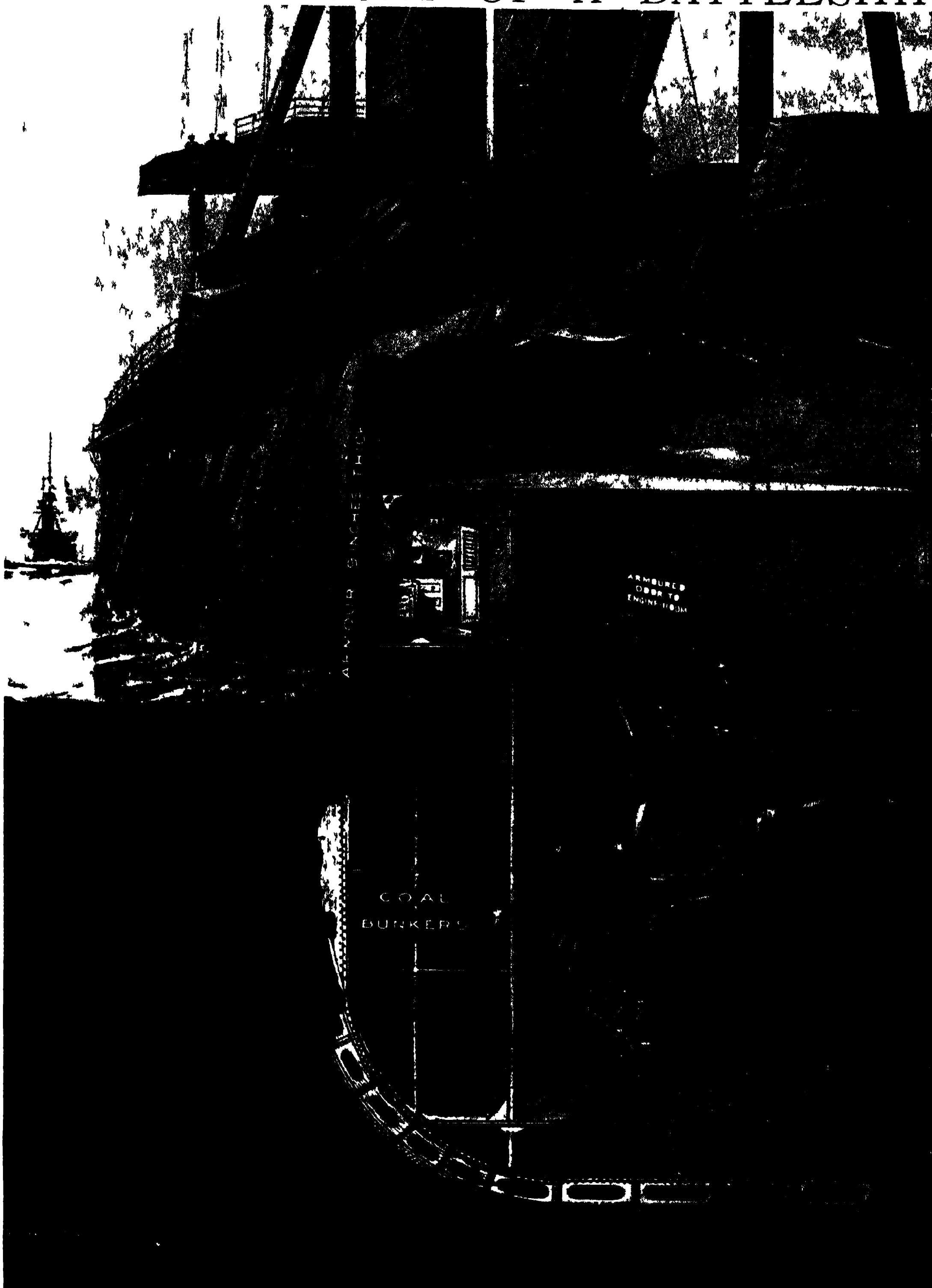
of the British Navy, the Hardcastle, is of any use at 5000 yards. The enormous shell of the 13½-inch gun, on the other hand, travels from the muzzle at a speed of about three thousand feet in a second.

This wonderful swiftness makes it easy to hit a mark at five or more miles, and the enormous force behind the shell keeps it extraordinarily true. That is why the big gun is better than a rather smaller gun: its greater muzzle energy keeps the shot straight to the mark at which it is aimed. In actual battle, our 13½-inch ordnance ought to hit once at least in every two shots, providing the enemy's vessels can clearly be seen, at a range from five to seven miles. The torpedo captain will be standing in the conning-tower, with his hand on the torpedo-pistol. He will be very busy doing very intricate sums. From the range-finder in the conning-tower he will be able to estimate roughly the speed at which the ship he is aiming at is going. He will also be able to calculate the range, and here, perhaps he will receive more precise information from one of the gunnery officers.

But at long distances his weapons will practically be useless; and even supposing the enemy's ship comes just within striking distance, the chances are he will miss her. Between the time he fires his pistol and the time when his torpedo covers 4000 yards, the ship he aimed at will be about a mile and a third from its original position. He will, of course, aim at the spot which he reckons the ship will reach; and so the whole thing becomes very problematic.

But in the case of a shell from a big gun, a ship moving at a speed will scarcely advance half her length between the time the shot is fired at her and the time it strikes her. Thus the big gun excels in both quickness and sureness of aim; the

THE STEEL COAT OF A BATTLESHIP

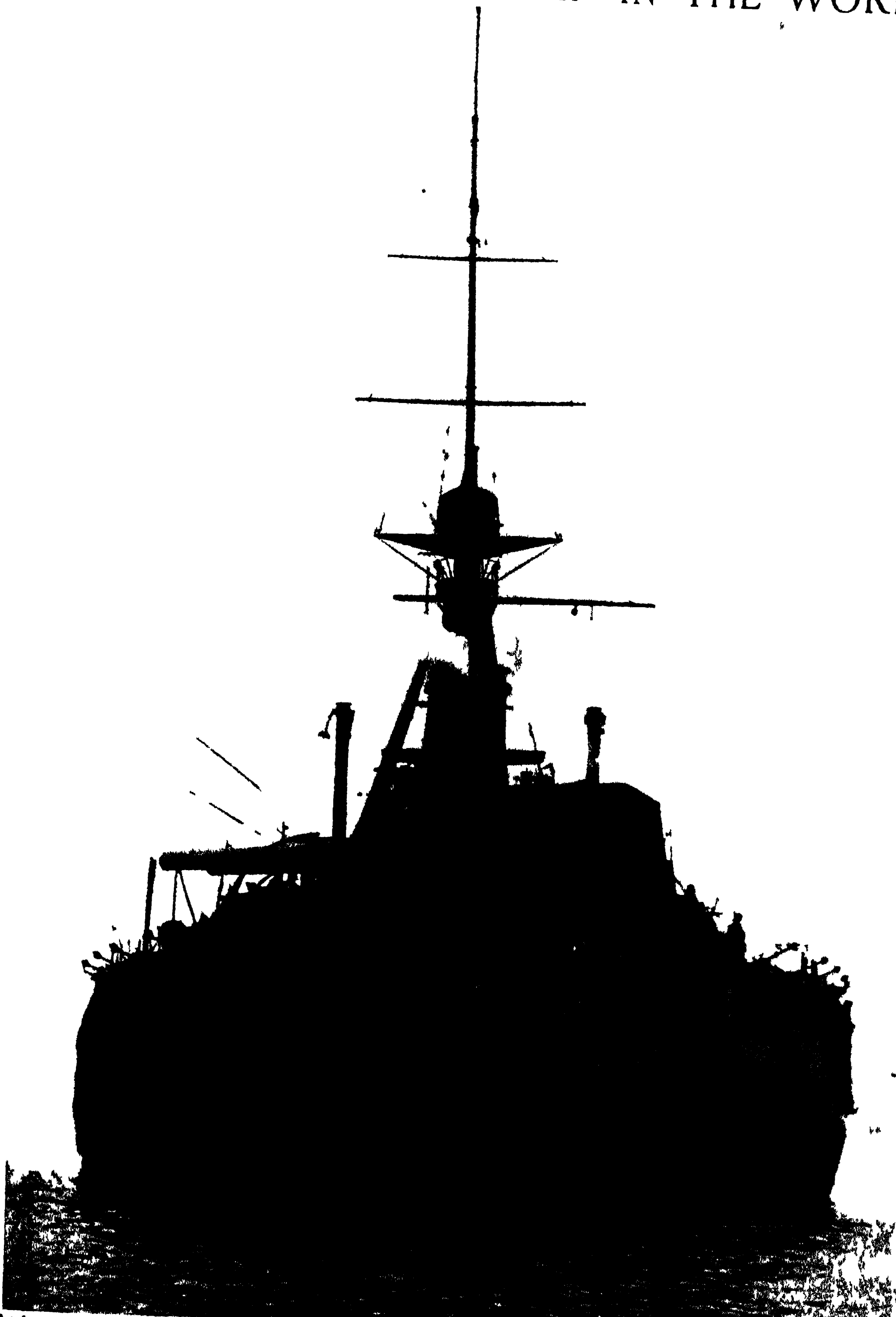


Hard, tough, thick armour-plates of carbonised forged steel protect the vital parts of a battleship, and the turbine engines, which are the power-giving heart of the ship, are still further shielded by an armoured deck and by bunkers of coal which act like the earthworks of a modern fort. It is still doubtful if the shell of big guns can get through modern armour at a fighting distance.

THE WARSHIP'S BOWS THAT CUT LIKE A KNIFE

This photograph of one of the latest armoured cruisers lying docked shows the great depth of a warship and reveals the sharp bows which, cutting the seas as with a knife and lessening friction, enable her to out-speed the best modern liners. H.M.S. Lion, one of our new battle cruisers, will go 33½ miles an hour—1½ miles more than the German cruiser Moltke, that now holds the record for speed in big ships.

THE MOST TERRIBLE SHIP IN THE WORLD



At least twice as powerful as the first Dreadnought, the Orion would not let any other ship in the world live for a quarter of an hour on a clear day within five miles of her ten 13½ inch guns. Every two minutes she can throw a broadside of steel and explosive with an energy of 700,000 foot-tons.

ten enormous lyddite shells which it throws every two minutes at the same target are swifter and deadlier than the torpedo. The torpedo is likely to play in naval warfare a part similar to that now assigned to cavalry in land warfare. The big gun will smash up and demoralise the enemy's fleet; and then, under cover of night, the torpedo craft will rush in and turn the defeat into an annihilating rout. Of course, improvements in the submarine and in the torpedo itself may soon make this weapon a quicker, surer instrument of offence. If this happens, the capital ship will have to be transformed.

But at the present time the battleship of the Orion class is supreme. All that the ablest minds in industry and science can devise, with the resources of modern civilisation to produce the utmost energy of destruction, is done by the machinery hidden in her plain, grey, and apparently simple hull and turrets. On the five turrets, containing the ten guns of the Orion, an extraordinary amount of inventive genius has been spent. The turrets are placed along the centre line of the battleship—that is to say, along the keel line running from the bow to the stern. This is a reversion to an old design in British turret-ships.

When All the Guns on a Battleship are Fired Together

The thing seems so clear that it may seem difficult to understand why the centre-line system was not adopted in our first Dreadnought. The fact was that all the great naval Powers—except the United States—were ready to sacrifice from 20 per cent. to 38 per cent. of the broadside fire of their battleships in order to retain a powerful bow and stern fire. If the turrets are placed all on the same level down the centre line, there will be only two guns available for firing at an enemy directly in front or directly behind.

The Dreadnought, and the Nassau, the Satsuma, and the Danton can bring each six guns to bear in an end-on fight. The Americans, however, got over the difficulty of combining a full broadside fire of ten guns with an end-on fire of nearly six guns. They kept to the centre-line system, but built the second turret higher than the first, and the fourth turret higher than the fifth. The guns in the two higher turrets fired over the top of the two lower turrets in an end-on action; while the third and middle turret was able to train its guns round either to the bow or stern, and so add practically two more guns, making six in all.

For some years no other nation followed the lead given by the United States. There was a general feeling that the Americans had taken too many risks for the sake of a theoretic advantage. What will occur, said all other naval constructors, when the terrific blasts from the two upper guns continually sweep above the lower turret? What will then happen to the men in the lower turret and to the mountings of the lower guns?

The Secret of the Tremendous Power of the New Battleships

Yet the Orion is a magnificent success. She carries much heavier guns than the Neptune. They are 13½-inch, weighing seventy-five tons, and casting a 1250 lb. shell; while the guns of the slightly older ship are only 12-inch, and throw an 850 lb. projectile. The Orion has two superimposed turrets; and when the guns from them are fired directly over the lower turrets, the men beneath are not inconvenienced in working their own guns. A blast with the enormous energy of 140,000 foot-tons—power equal to that exerted by 300 of the largest steam-hammers—is moving over the dome of metal just above the gunners' heads, and they scarcely feel it. And think of the strain on the structure of the ship when, with all five turrets swung in the same direction, she delivers the volcanic energy of destruction of a full broadside! Yet she only dips a little under the recoil, and then rises to give the next smashing blow.

The means by which this terrific power is wielded, without putting any strain on the ship and crew, is the grand secret of the construction of the Orion. She is the most mysterious as well as the most powerful of battleships. Her secret resides partly in the design of her turrets and mainly in the way in which her giant guns are mounted. Here it is that at present we hold over every other nation a great advantage, not only in the number and armament of our ships, and in the number of our men, but in the creative faculty of inventiveness.

The Gigantic Gun that is Too Powerful to be Mounted

It is fairly easy nowadays for a great industrial nation to build a monster gun. For some years the Americans have had a 14-inch naval gun ready; the Germans are making a gun of the same kind in answer to the 13½-inch ordnance of the Orion; and we, in turn, intend to set the pace again with a 15-inch armament. Indeed, we possess a 110½-ton gun, firing a vast

THE STEEL ROOM AT THE TOP OF A SHIP

With position-finders and other instruments, gunnery officers in the steel fire-control station, at the top of the mast, find the range and speed of hostile ships. They telephone their observations to the fire-control officer, who sits in an iron room in the depths of the vessel, and this control officer, by electricity, fires guns that he cannot touch, at an enemy that he cannot see.

THE GUNS OF A DREADNOUGHT RING OUT ACROSS THE SEAS

In delivering a broadside, the armoured turrets swing round together at the touch of a lever, with all their guns on the enemy. Here the 12-inch guns of the Dreadnought are seen shooting at a gun trial; at least one in every two shots will strike home, at five to seven miles, now that smokeless powder is used.

INSIDE THE WORKS OF A MODERN BATTLESHIP

"It is like being inside a watch," said a well-known man on going over a Dreadnought. This photograph shows the working chamber of the big-gun turret of a Dreadnought, the most wonderfully complicated piece of machinery extant. Here we see the part occupied by the means of communication; and a gunner is moving the lever which works the ammunition hoist, and lifts a half-ton shell into the seventy-six-ton gun, ready for firing by electricity.

explosive shell. But making a gigantic gun of the modern sort is one thing, and constructing a mounting which will enable a ship to stand the shock of ten guns firing an immense charge of cordite is a very different thing. It is not as though the gun were placed on a firm foundation; it is put into a turret which swings round on a turntable at a touch on a lever. It must be exquisitely balanced; and nearly all the smashing force of its recoil, when its charge of 170 lb. of lyddite is fired, must be taken by some mechanism fixed in the revolving turret.

In the Turret of the Orion—the Most Wonderful Mass of Machinery in the World

The writer has been permitted by the Secretary of the Admiralty to go over the Orion on her return from her gun trials, but all that he has liberty to say is that the new mountings were a success. The interior of one of the turrets of the Orion forms the most wonderful mass of machinery existing in the world. Besides manufacturing with its two guns an explosive force of 140,000 foot-tons, the structure contains compressed air engines and machinery worked by hydraulic and electrical power. Practically everything is done by machinery on a modern battleship. In the Orion there are several boilers for creating steam power, and probably more than fifty engines for converting this power into locomotion, electricity, compressed air, and hydraulic force. In the centre of the ship, protected by the heaviest armour, and with bunkers of coal on either side, acting as a kind of earthworks, is a Parsons turbine of great horse-power, which drives the Orion at a speed of twenty-six miles or more an hour. Nine hundred tons of coal and 2700 tons of oil are used together in the furnaces, and the scorching fumes which they produce are circulated round and round the tubes of the boilers to get as much energy as possible out of the fuel.

How a Half-ton Shell is Lifted from the Magazine into the Gun

The boilers are composed of layers of little pipes, those in the Orion having been made by Babcock and Wilcox. They have several advantages over the big, hollow boiler. They enable steam to be got up very quickly—a great thing in a battleship; and if they are pierced by a bit of shell they are easier to repair. A modern battleship, however, would not be injured if her boiler were struck. In a few moments the great turbine engine would be attached to another boiler in a different part of the hull, and before the ship had slowed down her four screws would be whirling at about their ordinary speed. If the boilers were much damaged, so that all the steam available was needed to keep up the speed of the ship, the army of sailors in the depths of the wounded leviathan would have to work very hard while the battle lasted.

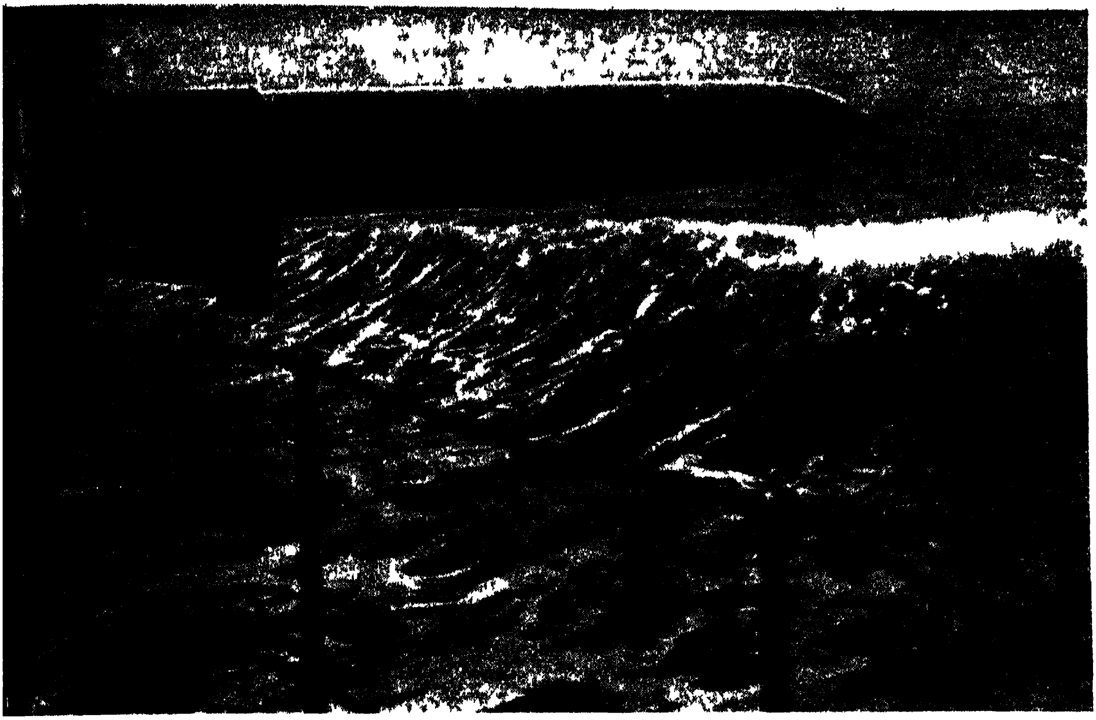
But in the ordinary way little manual power is used on a modern battleship. Nearly everything is done by compressed air, hydraulic power, and electricity. Take, for instance, the firing of the two big guns. The actual hand labour of the gunners in the turrets is light.

They are highly skilled engineers entrusted with the delicate care of a huge mass of exquisite and intricate machinery. They neither load nor fire the gun. The great shells are stacked in compartments in the bottom of the ship; a large steel claw travels above the compartments, drops down, seizes a shell, and carries it to a lift running up to the turret. All that the gunners have to do is to open the breech of the gun, and then the shell—more than half a ton in weight—is seized by another piece of machinery and placed in the gun. No hand touches it during its journey from the magazine into the gun.

How the Tremendous Guns of a Modern Battleship are Fired

Still more extraordinary is the way in which the gun is fired. High above the battleship is the fire-control station. This is a platform supported by two long, huge steel tubes. When the ship is cleared for action, the mast which usually rises from the fire control is removed, lest its fall should endanger the gunnery officers. From their tower of vantage they study the enemy's ships with telescopic range-finding instruments, and by means of speaking-tubes and telephones they communicate their information to the chief fire-control officer. He sits at a table with some assistants in a room in the most heavily armoured depths of the ship. He can see nothing and hear nothing, but it is he who directs and fires the ten great guns. He is principally a mathematician. The men high above in the fire-control station telephone to him their calculations of the speed of the enemy's ship and the range necessary to hit her. The fire-control officer gives the order for one gun to be trained on the hostile battleship. The men in the turret give their gun the elevation worked out by the fire-control officer. This officer then fires the gun by means of electricity, and

THE DOOM THAT STEALS THROUGH THE SEAS

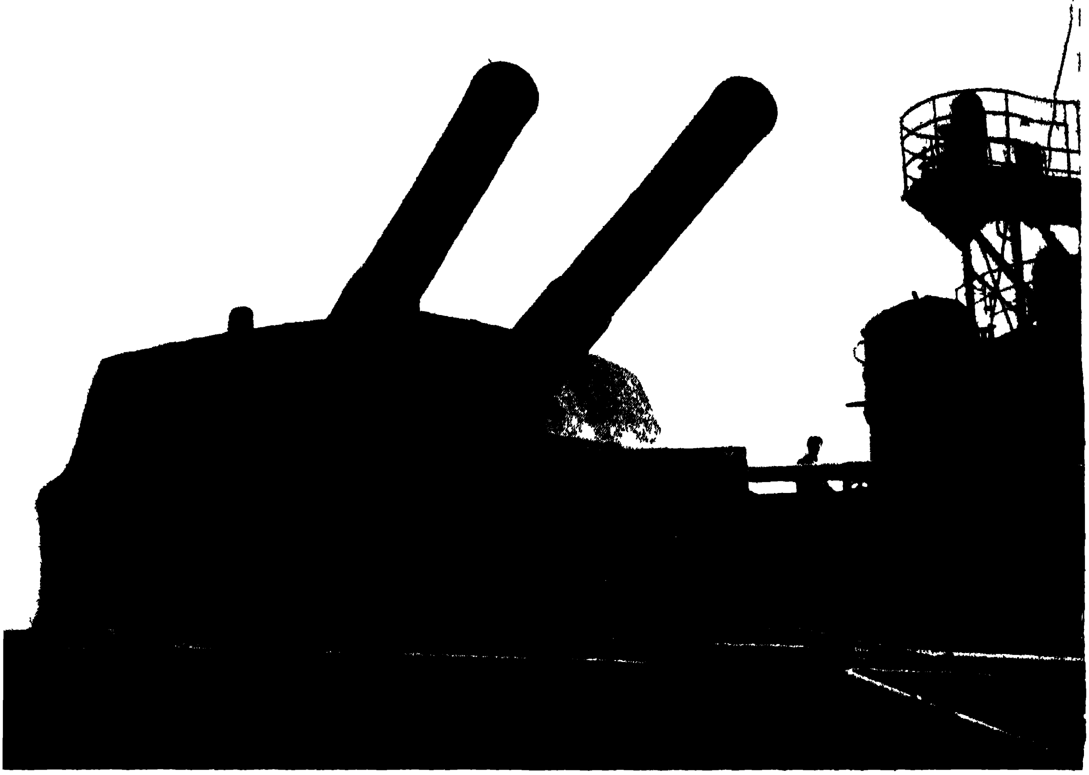


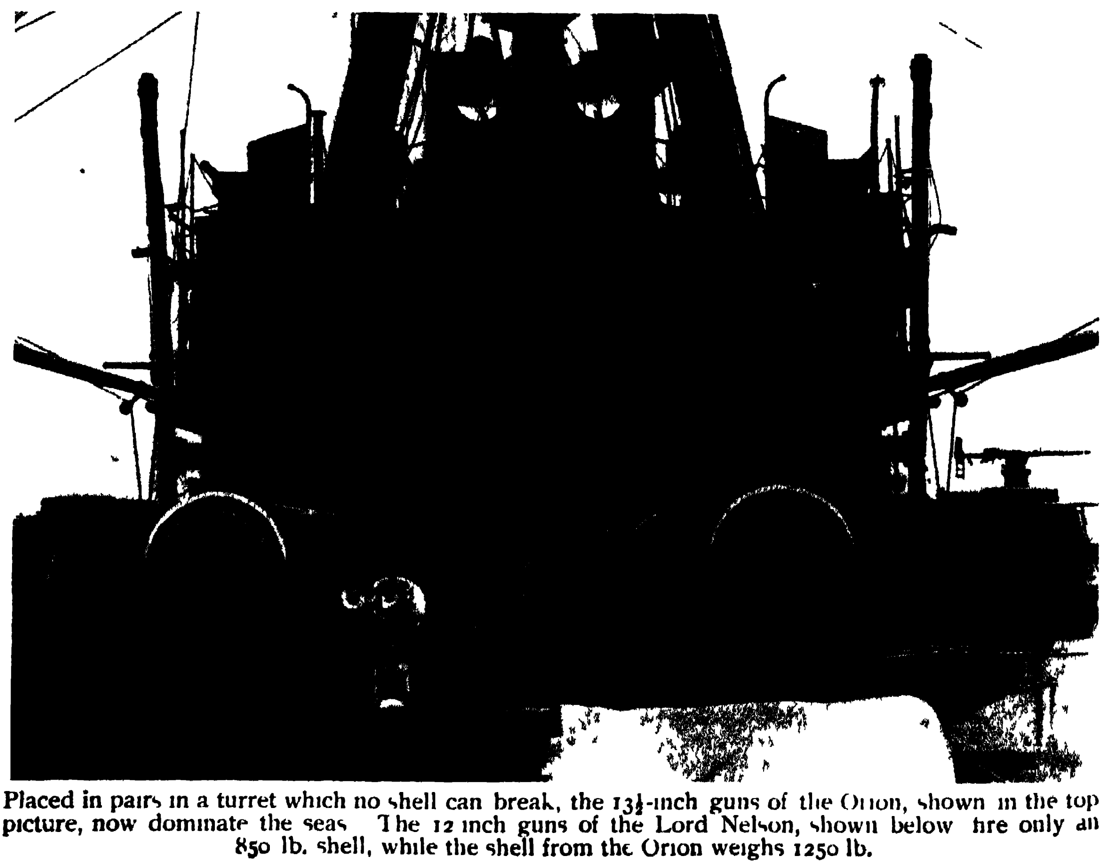
A TORPEDO SETTING OUT ON ITS JOURNEY DRIVEN BY AN UNSEEN ENGINE

A TORPEDO IN THE STEEL TUBE FROM WHICH IT IS FIRED INTO THE SEA ON ITS JOURNEY OF DEATH

Here we see a torpedo in its casing with a picture of another at the moment of starting its journey of death. Fired, by compressed air, from a steel tube the torpedo shoots forth on its work of destruction. Behind the screw, worked by a little unseen engine, are the rudders. The angles at which these are set determine the depth below the water line at which the torpedo strikes the doomed vessel.

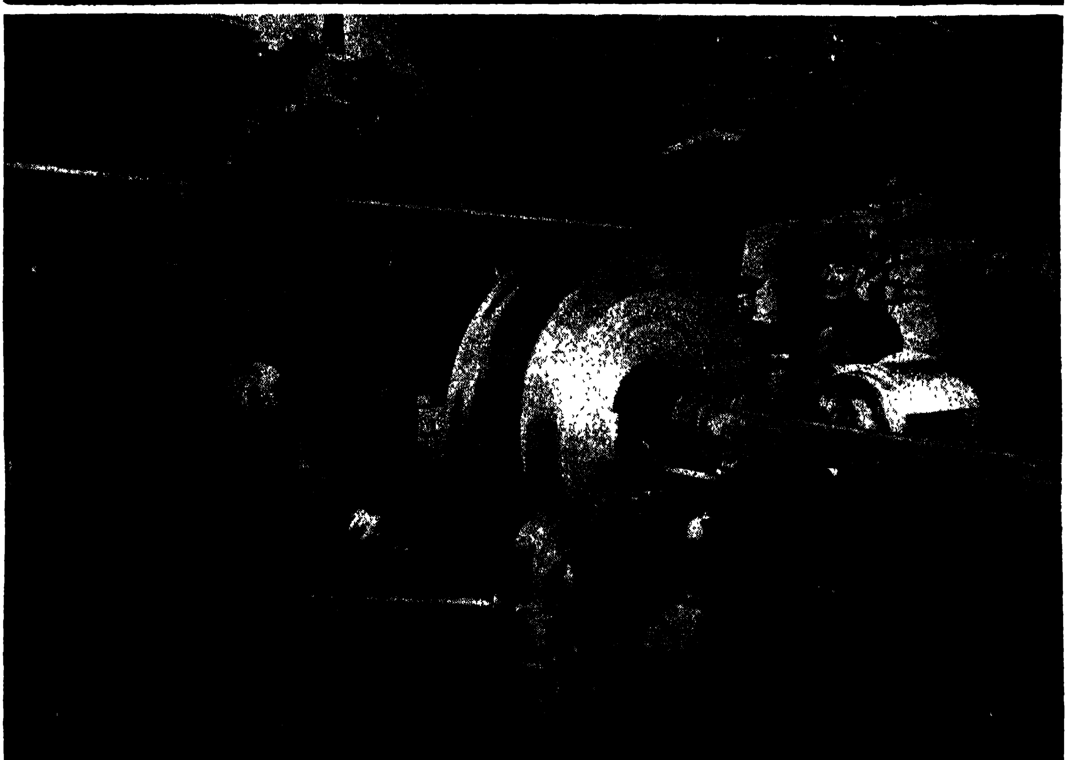
THE NEW GUN THAT RULES THE SEAS





Placed in pairs in a turret which no shell can break, the 13½-inch guns of the Orion, shown in the top picture, now dominate the seas. The 12 inch guns of the Lord Nelson, shown below fire only an 850 lb. shell, while the shell from the Orion weighs 1250 lb.

LOADING THE BIG GUN ON A DREADNOUGHT



The huge shells used by the 13½-inch gun are raised by a lift from the magazine, and placed by machinery in the breech of the great gun. The shell weighs more than half a ton; and the lower picture shows a mechanical rammer which has just driven the shell into the breech. All the mechanism is worked by hydraulic and electric power and compressed air.

his assistants watch the fall of the shell from their tower high above the deck. The odds are that the shot fails to strike the mark; it falls too short or too far. But by measuring the distance between its splash and the enemy's ship, the exact range is found. Again the fire-control officer and his assistants work out their calculations, and in the two minutes necessary for reloading the first gun they are ready.

The Torpedo Captain who Stands with His Hand on a Pistol

Overlooking the bows of the battleship is a low, heavily armoured kind of little turret; between its massive dome and the thick cemented steel that form its sides there is a slit too narrow for a shell to enter, but wide enough to enable a man to see for miles across the sea in front and on either side. This is the conning-tower. In it stands the captain of the ship, and he also has instruments for finding the range and speed of the enemy. This work is done for him by the torpedo captain, who remains by his side. The torpedo captain has a pistol, and whenever he presses the trigger a twenty-one-inch torpedo is fired from a gun through the water at the bottom of the ship. The captain of the battleship, on the other hand, does not fight. It is his sole aim to manœuvre his ship into such a position as to give his fire-control officer the best opportunity for using the great guns. So much trouble has been taken by all the great navies to give their battleships a powerful end-on fire that any man who is not an expert would think that a bow or stern fire of six guns is of supreme importance. It might be supposed that when a ship only shows to the enemy its narrow bow, which increases at the most to a breadth of barely thirty yards, it would present a very small mark. It might also be supposed that when a ship turns to fire broadside at the enemy, and presents in turn a length of about one hundred and eighty-two yards, it would be a much easier target.

The Man who Aims the Gun which May Destroy a Town

All this, however, is quite wrong. It is hardest to hit a ship that lies broadside-on, and easiest to hit her when only her bow or stern can be discerned. Let us explain the matter from the point of view of the fire-control officer. His great difficulty is to get the exact range of the enemy. The big modern gun, fitted with special machinery, and having an immense muzzle energy which keeps the shell true to its mark over a long distance, can be aimed straight by any well-trained gunner. The problem is to set the gun at the exact elevation necessary to make the shell fall at, say, 9000 yards. An almost microscopic difference in the tilt of the gun will cause the shot to fall, say, 9050 or 8950 yards. The shot may be quite straight, and yet go over the ship or splash harmlessly in front of it, if the ship is steaming broadside-on. For she then presents only her breadth of thirty yards. If, on the other hand, she is steaming end-on—let us say she has given up the fight, and is running away with only her stern showing—then the shot fired at her will tell, no matter whether it is fifty yards short or fifty yards too far. Elevated to a range of 9050 yards, the shell may plough through funnel or fire control and smash on a turret near the bows; while at a range of 8950 yards it may strike one of the stern turrets and jam it.

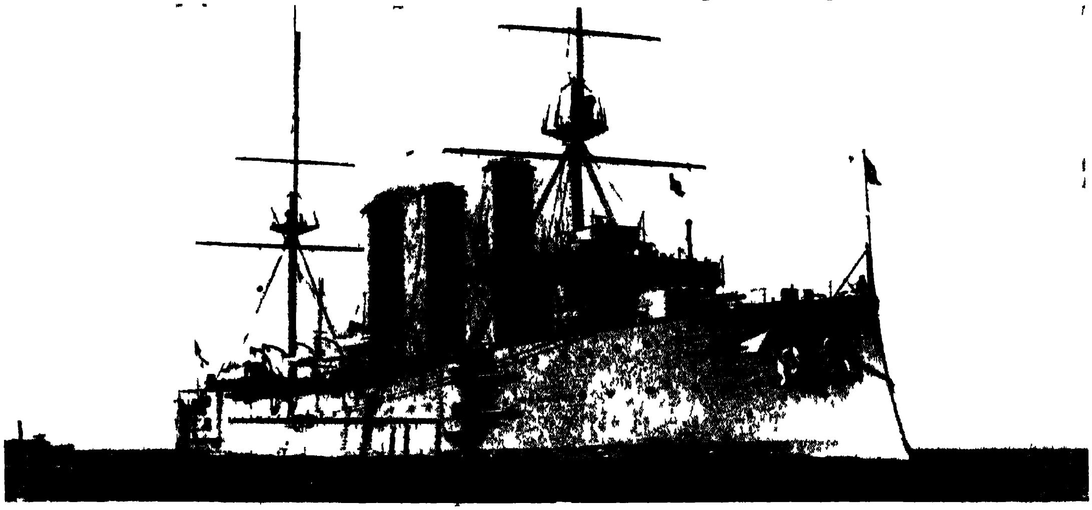
Thus the captain in the conning tower will manœuvre to get his ship within about five miles of the enemy, and broadside-on. His ship will then present a target of only thirty yards, and the fire-control officer will, by that time, have got the exact range and be discharging ten guns full at the enemy every two minutes or so.

Will the Next Great Naval Battle Last Fifteen Minutes?

In this case the enemy might be sunk in six minutes; indeed, there is more than a possibility that, if the first broadside of five and a half tons of lyddite and forged steel struck clean home, the awful work of destruction would practically be suddenly over.

It is natural to ask what would happen if the fire-control station of the Orion were destroyed during action. A few years ago it would have meant the utter disorganisation of a gigantic battleship. On the Orion, however, it would scarcely interfere for a minute with the work of the fire-control officer. He would not be killed, as in the days when he was working the guns from the fire-control station; and a few seconds after the station fell, another set of men, in another place, would be working with telescopes and range-finders and sending him a stream of information. How all this can be done when the fire-control station is shot away is another mystery of the Orion which must not be revealed. But is it not strange that the modern battleship, with its unparalleled complexity of machinery, should be so wonderfully simple in its fighting action? A battle between two great modern

MAGNIFICENT SHIPS OUT OF DATE

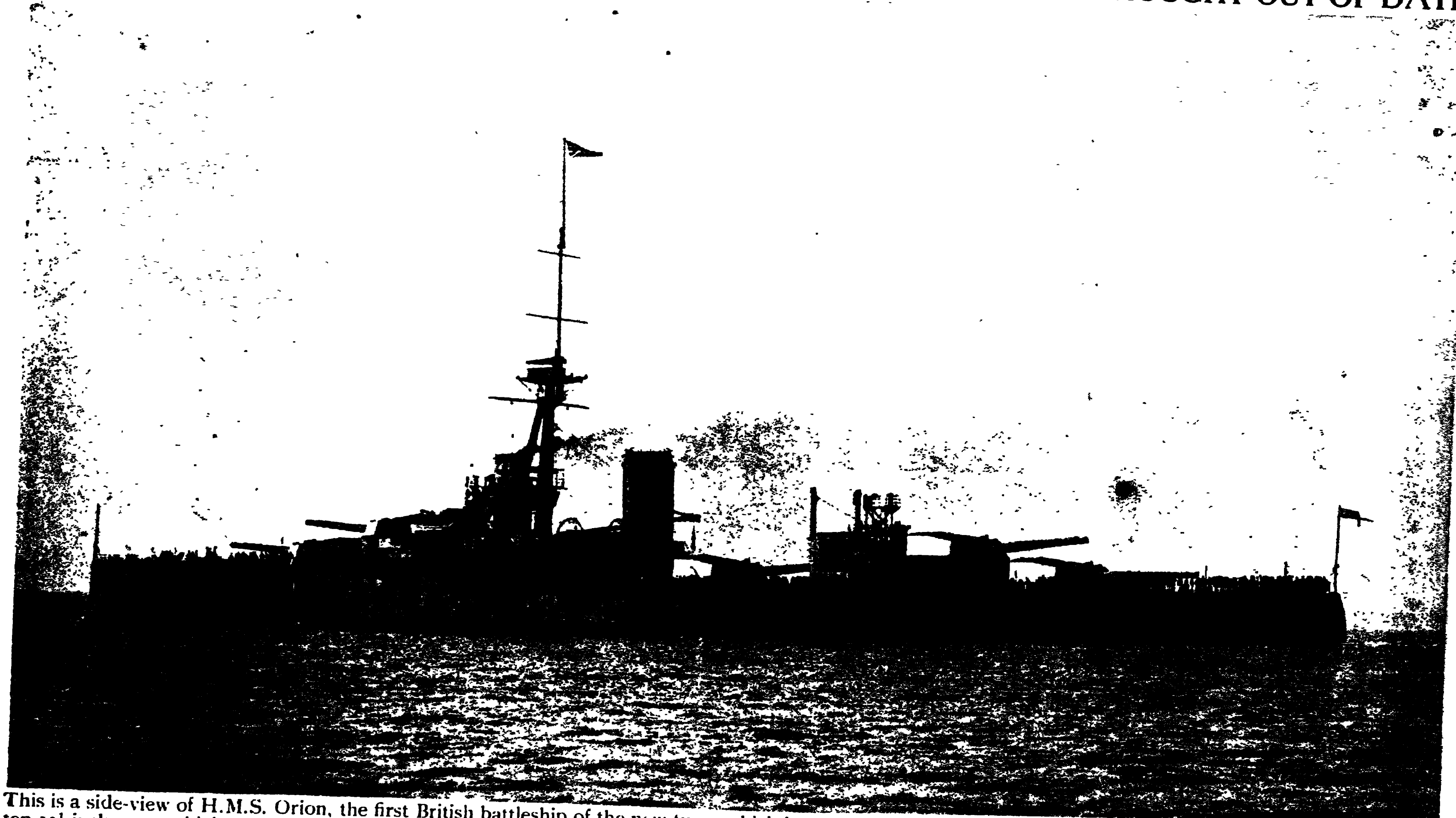


Though still in commission, these picturesque warships, cruisers of the pre Dreadnought days, could not stand against the plain, grim Orion, which could sink both in a few minutes at a distance of perhaps more than seven miles. So marvellous is the advance of naval science that in nine years huge ships such as these are out of date.

THE HISTORIC MOMENT WHEN ALL THE NAVIES ON THE SEAS BECAME OBSOLETE

This picture shows the launch of a ship which confounded the naval calculations of all countries. When the first Dreadnought was launched and armed, every other warship in the world became obsolete. That was only seven years ago, and now the Orion has appeared—a super-Dreadnought—and all our Dreadnoughts, and all the Dreadnoughts that other nations have built in imitation, have suddenly grown out of date, for one Orion is worth two Dreadnoughts.

THE AMAZING NEW BATTLESHIP WHICH HAS THROWN THE DREADNOUGHT OUT OF DATE



This is a side-view of H.M.S. Orion, the first British battleship of the new type, which has created a world-wide revolution in naval construction. She carries ten 13½-inch guns which are able to fire, every two minutes, five and a half tons of steel and lyddite ; and the force of the discharge can carry them twenty-one miles. No existing warship could survive for six minutes within five miles of the Orion.

The photographs on these pages are by Messrs. Symonds and Co., Reginald Silk, and Stephen Cribb

warships really resolves itself into a duel between two men—the two fire-control officers. The captains of the two hostile ships act as seconds, and scheme to get the best position for their men.

The two armies of sailors and marines of all ranks, the engineers, stokers, artificers, and the rest of the crews, are only humble assistants in the duel. They see that the powers at the command of each duellist—electrical power, hydraulic power, the power of compressed air, the energy in many thousands of tons of coal and oil, and in vast stores of cordite and lyddite—are employed to his advantage.

The Man who Fires a Gun He Cannot Touch, at an Enemy He Cannot See

The two men themselves each sit in a closed room of steel in the black heart of their ships, calculating against each other like two chess-players playing a match by cable. They see nothing and hear nothing of the outside world; nothing reaches them but information coming through the speaking-tubes and telephones from the fire-control station and the conning-tower. In essence, it is the game of one mind against another mind—a slight slip in a rapid calculation, and the other player gives check, delivering his answering move from the mouths of his ten guns. A slight pressure on an electrical button, and he fires his broadside, and down the tube from the fire-control station comes the information that he has struck home. The awful game, played by two men who see nothing of it, will decide the fate of two or more of the great Powers of the world. There is surely a wild and dreadful sublimity in this duel between the two fire-control officers of opposing battleships.

The Fire-Control Officer—the Greatest Man in the Navy

Practically everything in vessels of the improved Dreadnought type has been subordinated to the needs of the fire-control officer. It has been found, for instance, that he cannot manage more than a certain number of big guns. So the only means of adding to his terrible powers is to increase the energy and smashing force of his tremendous weapons. For this reason our naval constructors have for some years devoted themselves to the laborious task of working out the centre-line system of turrets and superimposed turrets, and mounting a bigger gun. The 12-inch ordnance has given way to the 13½-inch, and now the hundred-ton naval gun is only waiting for a proper mounting, so that it can be given to the fire-control officer wherewith to fight his duel. To free him from distraction, and place all weapons of importance at his command, the secondary armament has been removed to another and smaller ship. He has not to take any defensive measures; he is force incarnate—swift, brutal, aggressive, destructive, overwhelming force. All he has to do is to strike as surely and as often as he can, and his captain will see to it that he is put in the best position for striking.

The great problem connected with the 13½-inch gun relates to its power over the armour plate. It is still a question if the big gun has conquered the new armour. For many years the battle between the gun and the armour plate has raged; and for a long time the armour plate was victorious. The Orion carries thick armour round her vital parts. She has also an armoured deck and a false bottom. To return to our first image, she is a steel raft, floated by means of innumerable little, water-tight boxes of steel and iron. If a number of these boxes were blown away by shells and torpedoes, the Orion would not sink.

The Extraordinary Battle Between the Big Gun and the Armour Plate

Practically she is unsinkable; and if two or three holes were torn in her side, the result would be merely that her speed would be retarded. Only the 12-inch gun could be brought against her; and in spite of all that has been loudly said about the new 12-inch gun, it is very doubtful if it is victorious over the armour plate.

Modern armour was invented by Krupp in 1893, and has since been improved by British manufacturers, who keep their processes secret. Usually it is formed of steel mixed with small quantities of nickel, chromium, carbon, and one or two other things. It is cast, heated, and forged, like the gun, under a hydraulic press. Then it is reheated and rolled and planed and cemented. It is put in a cementation furnace, where its face remains for some weeks in contact with specially prepared carbon. After this it is plunged in an oil bath, reheated, cooled, heated again, and bent in a bending press, and again heated and chilled. Then it is machined and drilled, and again heated. Thus is formed the hardest and most resistant substance that human skill can devise.

Hard armour of this sort cannot be perforated by any kind of gun; it must be cracked. Shells filled with high explosives are useless against it in the ordinary way.

If a lyddite projectile explodes on touching the plate, it does no damage. Shells are made of forged, hardened, and tempered steel, but the very hardest of them is shattered against a thick, cemented plate. In 1894, however, Russia made some startling experiments with a new kind of shell, that shot through armour plates. A thimble of wrought iron or soft steel was placed over the hard point of the shell. When the capped projectile was fired against armour it had an extraordinary effect. For the soft thimble supported the hard point, and prevented it from being crushed, and so the shell went clean through the hard-faced layers of steel.

A Little Thimble of Soft Iron that Breaks Through Ten Inches of Hardest Steel

This invention of an armour-piercing shell was first thought to have decided in a final way the battle between the big gun and the cemented plate. In the Russo-Japanese War, however, no thick belt or turret armour was perforated; and even at the present day it is very doubtful if the 12-inch guns, carried by every big battleship in commission except the Orion, can do any serious damage against heavy armour at fighting distances. Breaking through a straight, level piece of plate, erected as a target, is an interesting test of the power of a gun and its capped shell. On a battleship, however, all the armour is curved and in motion, and the projectile must strike normally on the plate in order to drill its way through. Thus the chance of perforation is really small; and in spite of general opinion to the contrary, armour has remained up till now in advance of artillery. Has the Orion changed this position of affairs? Undoubtedly she was designed to do so. Her guns are reckoned to have one-fifth more power of penetration than the ordnance of the Neptune. It has been widely reported that the armour-piercing shell of the Orion can get through 12 inches of the hardest and deepest-faced plate at a distance of seven miles.

The Battleship that will not Let Anything Live Within Five Miles

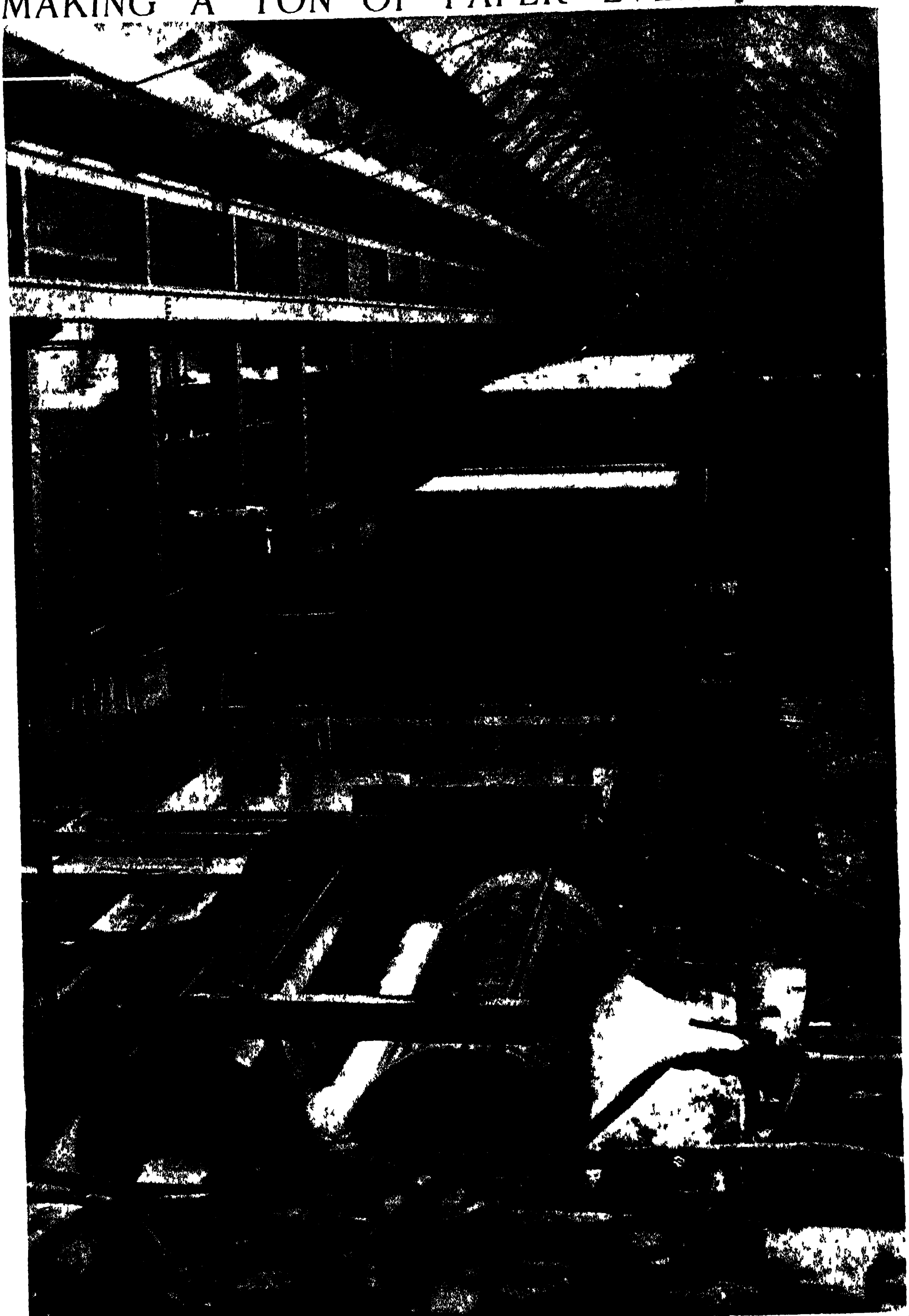
The writer feels certain that this could not be done in actual warfare. At a range of seven miles the gun-fire of our most powerful battleships will be directed at the less protected parts of the enemy's vessel; it will very likely damage some of the gun-mountings of its secondary armament, and —with luck—jam a big-gun turret. At five miles, however, the Orion is expected to kill anything of mortal making; and here, perhaps, armour will begin to give way to artillery. But, in the judgment of the gun-maker himself, the gun is not yet triumphant, for he is busily inventing weapons of greater power.

As things now stand, in this world of warring interests, national ambitions, and racial jealousies, the modern battleship is a noble instrument of defence for an island kingdom, whose energies are almost entirely absorbed in the arts of peace. She is a symbol. In her, on the one hand, are handed on the traditions Nelson bequeathed when, dying on the Victory, he left his country mistress of the seas. And in her, on the other hand, is represented the genius for invention and manufacture on which is based the modern civilisation of Great Britain. We front warlike nations that have many millions of soldiers, yet we are well defended against the huge armies of the Continent by our fighting sailors, who number only 131,000 men and officers. Much we owe, of course, to our insular position. But to make full use of that position we need our mines and blast-furnaces, our factories, vast dockyards, and great manufacturing centres.

One Naval Engineer of Genius is Worth More than an Army Corps

The traditions of James Watt have become almost as important to us in naval warfare as the traditions of the old admirals. We are, to a large extent, a nation of well-trained mechanics and designers of machinery; and we defend ourselves by our mechanical skill and our talent for devising mechanism—by all the activity, wealth, inspiration, and resources of our industrial civilisation. Instead of increasing our warlike power by a new army corps, we frame a novel sort of floating fort which sometimes more than doubles the striking force of its crew. In 1906, for instance, we held the lordship of the sea with the first modern Dreadnought; and now, only five years afterwards, we have produced in the Orion class a ship at least twice as powerful in fighting power as the Dreadnought. We have invented the new fire-control system, the Parsons turbine, and the new gun-mountings; we have a secret torpedo with marvellous range, and a submarine which, for ingenuity and efficiency on a small scale, beats the Orion. Directly or indirectly the British man of science, the British inventor, mechanic, and captain of industry are now part of our naval forces. Some of their mind and skill, their enterprise, and organising ability goes to the devising of the terrible machines of war that patrol our seas.

MAKING A TON OF PAPER EVERY HOUR



Here is an almost full length view of two papermaking machines, each about 200 feet long. The material enters the machine as a thin watery fluid. By a series of delicate and complex operations the composition is drained of water, and the fibres felted together to form over a ton of paper an hour on each machine.

THE KEEPER OF KNOWLEDGE

The Story of the Paper which Preserves the Store of Human Knowledge, and Makes the Thoughts of Men Immortal

AN INDUSTRY THAT DESTROYS IGNORANCE

Few industries are so compacted of hidden romance and fascination as that whose product is one of the least considered of commonplace articles—a sheet of paper. Paper is so abundant, its uses are so many, that it seems as inevitable as air. Those of us who have grown up in an age in which paper has been exempt from taxation, with a Press which has known no restrictive impost, cannot readily imagine a time in which paper was scarce and dear, the luxury of the few. Still less can we picture the dark days of an earlier epoch in which paper had no existence.

Without water, which is the paramount gift of Nature, every living thing would perish; without paper—which is an artificial creation the work of man's hands—civilisation would perish intellectually. Without paper there could be no diffusion of knowledge. The art of printing would have been valueless had there been no paper. We might convert the hide of every available animal into parchment on which to score our records without furnishing a substitute for paper. The quadrupeds of the world are not illimitable, but the uninterrupted supply of paper, like seed-time and harvest, must not fail.

All the learning of the world is committed to paper. The secrets of health, of commerce, of invention and industry, all the music of the dead immortals, all the philosophy and eloquence and varied poetic glories of ancient and modern seer and singer—all is bequeathed to us on paper. Newton had to pause in his mighty task of establishing the mechanics of the solar system until there came to his hand a paper giving him a measurement of the earth's magnitude; the world had to wait for the steam locomotive until George Stephenson learned to read, so that he might master the secrets whose explanation was to be won only from the records of science, printed on paper.

But for paper, Shakespeare and Milton and Dante would have come down to us in mutilated versions preserved by a few illuminated manuscripts, or by word of mouth from minstrel and stroller. Galileo would have suffered in vain; Harvey's discovery would have been made to be repeated again and again; science and learning and travel would each have been confined within narrow boundaries, the knowledge of each restricted to a narrow circle of men. The need for paper grew in time to be almost as essential to the advancement of man as oral speech. How did men, reaching out from the wilds towards the civic life, arrange their affairs without it? We cannot tell when man discovered the earliest suggestion of writing, of which paper was to be the ultimate medium. Thieves and tramps and gipsies have to-day a code of written signals, scrawled upon gates and walls and trees, for the guidance of their followers.

We cannot say at what remote period of time such an art had birth. Certainly the idea of blazing a trail in the trackless wilds did not originate with the pioneers of modern days. There are preserved to us many specimens of the cave man's art, wrought upon rock and flint and bone with the primitive implements ready to his hand, but we cannot judge what signs he would employ, figured upon soft ground or upon the trunks of trees, or upon rocks exposed to view in some path in the wilderness commonly followed by himself and his fellows. Five great systems of writing have been independently evolved, each a writing made up of symbols representing either things or abstract ideas. The earliest was the Egyptian picture-writing. Upon that was based the first of alphabets, the Phœnician; from

that sprang two hundred variants, of which fifty are still in use in the world to-day. These languages were inscribed, with various engraving tools, upon stone, upon clay, upon metal. The oldest known code of laws, the Code of Hammurabi, who reigned twenty-two centuries before Christ, is inscribed upon a block of black diorite. The British Museum preserves a Babylonian tablet bearing an inscription relating to Sargon I., King of Akkad in 3800 B.C.

The Tax-Collector with his Load of Receipts on a Donkey's Back

From inscription upon stone the next step was the adoption of clay as a medium, the clay, inscribed when in a plastic condition, being afterwards baked or sun-dried to render the record durable. Clay tablets relating to business transactions of all sorts are in existence which carry us back to the twenty-fourth century before the Christian era. When we remember the difficulty that Sam Weller found in expressing himself in terms of affection on paper to his lady-love, we cannot but wonder how the ardent swains of ancient Egypt and Babylonia contrived to do justice to their feelings when inditing tender messages on damp clay. The task of the tax-collector was an arduous one. He had to give receipts, but these consisted, not of slips of paper, but of a donkey-load of broken pottery, called potsherds, one of which he had to tender, with an acknowledgment scratched upon it, in exchange for each legal tribute received.

But the astounding civilisation of the ancient East, which can be traced back for over seventy centuries, recognised that a better way of writing was to be found than inscriptions upon stone and metal, though these materials had to be retained for laws and treaties and declarations of abiding importance. The ancients discovered the first and only predecessor of paper. It was papyrus, from which paper takes its name.

How the First Sheet of Writing Paper Came into the World

Papyrus is a species of sedge, rooted in water, and growing to a height of from eight to ten feet. There was inspiration in the creation of papyrus as writing material. It marked an advance in inventive ingenuity as great as was the formation of the alphabet upon the picture-writing of the Egyptians. The Egyptians had no model; they began independently with their papyrus, cut the stem into thin strips, placed these together longitudinally with pieces laid at right angles, beat them, and soaked them, so causing the strips to adhere, smoothed and perfected them, and, lo! the first sheet of writing material had come into the world.

We know that this material was in use at least thirty-five centuries before the Christian era. There exists in the "Papyrus Prisse," a work discovered in a Theban tomb of the eleventh dynasty which purports to be a copy of a treatise relating to the fifth dynasty, that reigned about 2500 B.C. Lower Egypt is the gift of the Nile, which gave the world its first true writing materials. Papyrus is one of the vegetable growths which year after year chokes the Nile with 500 miles of "sudd," and that sudd has at last been rendered commercially valuable by its conversion into a fuel which will take the place of coal for steamers engaged in developing the land on either side of this life-giving river, where penmanship had its inception.

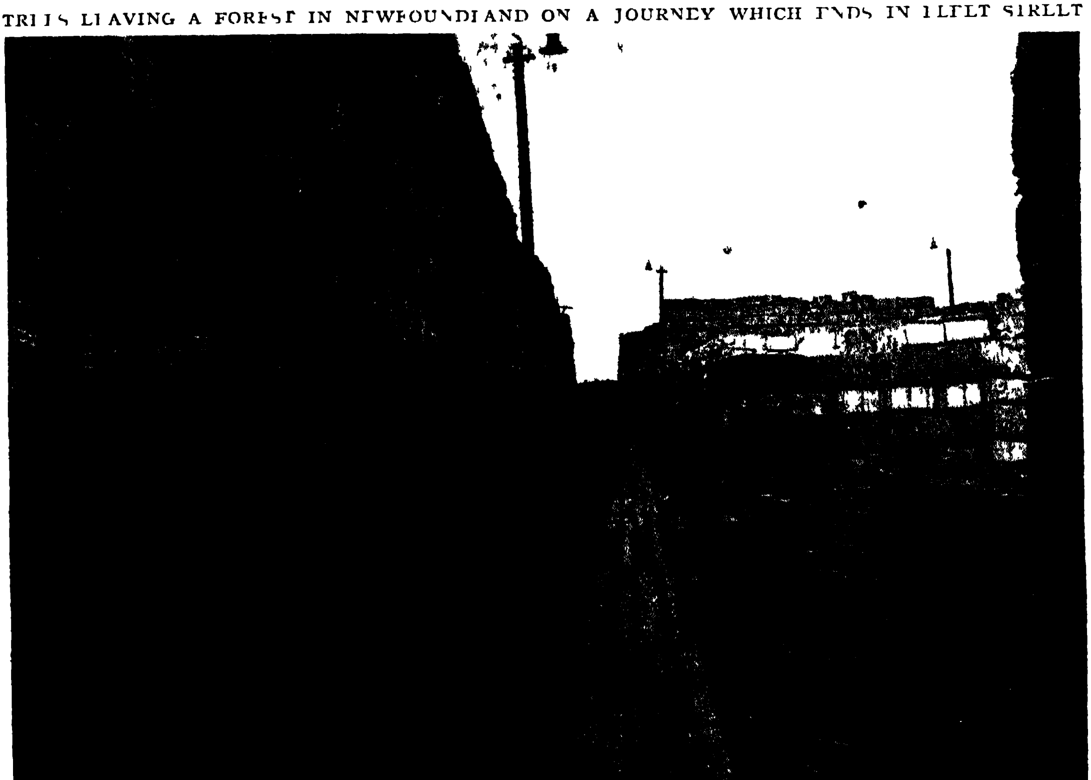
Papyrus became the medium for the penmen of old Egypt, the pen itself being a reed, and the ink made from some animal carbon, and coloured black and red. Although known to early Greek writers, papyrus did not become generally used among the Greeks until after the time of Alexander, when it was extensively exported under the Ptolemies.

The Chinese Labour from which the Paper-Works of the Western World have Sprung

Alexander, then, gave the papyrus to Europe. In the course of his career of conquest he overthrew the ancient city of Maracanda, later to rise anew as Samarkand, which, ever since its capture by the Arabs in 712, has been a sacred city to Moslems. Now, while Alexander was sighing for new worlds to conquer, there was a teeming civilisation in China of which he knew nothing. The Chinese had progressed beyond the comparatively rough-and-ready methods of the writers upon papyrus. They had from remote antiquity been making paper, true paper, of silk waste. We make silk to-day from a paper base, inverting the old Chinese process. When, in the eighth century, the Arabs had become the great scholars of the world, the physicians, the poets, the scientists, they became involved in war with a Chinese army, and their chief joy was that they captured a number of Chinese artisans. Rome had sent to China for stolen eggs of the silkworm moth for the introduction of the silk-spinning industry into Europe; the Arabs rejoiced that their governor brought back to Samarkand Chinese craftsmen who could make paper from fibre. Chinese labour provided the

BRINGING A FOREST ACROSS THE SEAS

TREES LEAVING A FOREST IN NEWFOUNDLAND ON A JOURNEY WHICH ENDS IN FLEET STREET



"THE FOREST ARRIVES"—THE HUGE STACKS OF PULP AT THE ENGLISH PAPER-MILLS

Selected trees in a "paper forest" are cut down, then carried to the waterside for conveyance to the pulping-mill, where they are cut into logs, ground to pulp, packed into bales, and sent to England

first paper factory ever seen beyond the confines of the Celestial Empire, and from that small establishment set up in Samarkand twelve centuries ago have sprung all the paper-works of the Western world. The industry spread from city to city, to Bagdad, to Damascus, to Egypt, and to cities on the north coast of Africa. The Moors took the manufacture of paper with them into Spain. Spain had, in the latter half of the twelfth century, the first paper factory in Europe. To-day she supplies the world with the greater part of the esparto grass used in the manufacture of paper. She exports the very substance that appears so urgently necessary for her intellectual regeneration.

Although the wise men of China could undoubtedly make paper of vegetable fibres, the paper commonly used was of rags. But the conquest of the world by paper was not yet secured. With the decline of Arab power, the industries which they had established declined in the lands over which they had held sway, and it remained for Europeans slowly to revive and develop the industry which had come in the train of invasion.

The Paper on which Shakespeare's Plays were First Printed

It was in 1455 that Gutenberg entered into partnership with the man who enabled him to set up his first printing-press. Within a few years the first paper-mill was opened in England. The origin of the English paper-making industry is commonly assigned to Dartford, but the first mill was established at Stevenage or Hertford by John Tate, whose father was Lord Mayor of London in 1476. It was to this John Tate that Caxton referred in a book published in 1490. Henry VIII. was one of Tate's patrons, and visited his mill. The first paper-making enterprise of size, however, was that of John Spielman, of Dartford, a native of Germany, who settled in England and erected his mill in 1568. He was Queen Elizabeth's jeweller, but it was as a paper-maker that he counted. He employed six hundred workpeople at his mills, which were visited, history tells us, by thousands of curious sightseers. It has been conjectured that the famous first folios of Shakespeare were made at this mill, but Mr. Clayton Beadle, after much painstaking research, reaches the conclusion that, though the folios probably contained some of Spielman's sheets, the bulk were of German origin. Spielman was licensed in 1589 "for the gathering of all maner of linnen raggs, scrolls, or scraps of p'chment, pease of lymes, and clippings of cards, and oulder fishinge nettes, for the making of all or anie sort or sorts of white wrighting paper, and forbidding all other p'sons for the making of paper, for the space of ten yeres next." The spelling of the name, by the way, is given in the Dartford registers as "Spilman." Kent has not much water, but such as it has is of the right quality for paper-making, and the industry became firmly seated in the garden county, mills being set up, in course of time, in other districts.

The First Machine for Making Paper in England

The terms of Spielman's licence indicate the nature of the materials upon which he relied for the making of his paper. His wares, like those of all other makers down to the close of the eighteenth century, were entirely hand-made, produced sheet by sheet. The rags employed were beaten into fibres by rough-and-ready mechanical appliances which were worked first by hand, and afterwards by wind and water power. The process was so slow that the output was necessarily restricted, with the result that the store of raw material available quite sufficed to meet all demands. But, intricate as is the work of the paper-maker, it has not proved too complex for machinery. The first machine for paper-making was introduced into England by Henry Fourdrinier, a London-born man, son of one of the old school of hand paper-makers. He improved upon an invention of a French clerk named Louis Robert, to whom credit for the first paper-making machine is due.

Fourdrinier spent £60,000 in perfecting his machine, and brought himself to bankruptcy, his invention being shamelessly pirated. His machine first opened the way to the unlimited supplies of paper which the manufacturer can now command.

The Need for Finding a New Material from which Paper could be Made

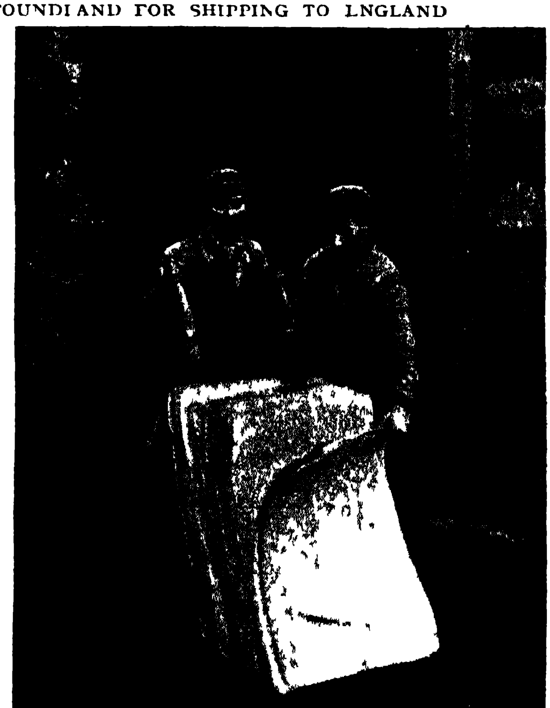
Fourdrinier's first patent was taken out in 1801, and from that time the development and improvement of paper-making by machinery has gone steadily forward, until to-day the machine which produces paper is one of the mechanical marvels of the age.

So far, rags had been obtainable in sufficient quantity to satisfy the paper-maker's needs, but with the removal of the stamp duty from newspapers, and the abolition of the tax upon paper in 1855 and 1862 respectively, the demand for paper assumed proportions such as to outrun

FROM THE NEW WORLD TO THE OLD

LOADING A CARGO OF PULP IN NEWFOUNDLAND FOR SHIPPING TO ENGLAND

THE PULP ARRIVES



THE PULP IN SHEETS AT THE MILL

Here are shown the departure of the pulp from a Newfoundland quay and its arrival at the paper mills in England. In the last photograph the pulp is shown in sheets, looking like inferior cardboard

the supply. Having got his machine and his market, the manufacturer was compelled to cast round for an entirely new source of supply of raw material. He had to find a substitute for the ready-made fibre of the rags of linen and cotton and other substances which he had been in the habit of employing. The silkworm converts the leaf of the mulberry into a viscous substance which, on reaching the air, can be spun into silk; the paper manufacturer had to find a vegetable substance which he could resolve into its constituent fibres and turn into books and newspapers.

The Wasp that has Held the Paper-maker's Secret for Ages and Ages

Probably he did not go to the wasp for guidance, but it was there that the secret lay. The wasp has been from the beginning of insect history masticating woody and other vegetable fibres and producing paper from them. And that is what the modern paper-making plant does. It is a colossal mechanical wasp, which masticates wood and grasses and the straws of cereals, and binds their fibre into miles upon miles of paper.

Esparto, or alfa grass, was the first vegetable substance with which commercial success was gained, and an extensive trade sprang up in paper made from this substance, and Southern Spain, and parts of Northern Africa, were exploited for the grass which had suddenly become an asset. But soon demand outgrew supply, as in the case of rags. Whereas the rag-gatherer had formerly kept the paper market going, now, with the spread of education, rags, plus enormous supplies of esparto, failed to satisfy the needs of the paper-mills. Rag returns about half its weight in paper; esparto yields about one-sixth of its weight. So other supplies had to be found.

The Search All the World Over for Materials that will Make Paper

The world has been ransacked for vegetable growths. In scores of city merchants' offices one may see little bundles of dried vegetable fibre, numbered and described. The traveller in the distant wilds sends these home, with a memorandum saying: "The natives call this substance so-and-so; they use it for such and such a purpose." The merchant seeks the advice of the botanists of Kew Gardens or of trade authorities: Will it make string or rope, or sacking or canvas? Best of all, will it make paper? Experiments are constantly in progress in chemical laboratories throughout Europe and America with a view to discovering new supplies from the growths sent from afar. Edison sent men on a world-wide tour to gather materials out of which to fashion filaments for his incandescent lamp, but the paper-maker has men constantly out and about the world.

He gathers flax from Russia, Turkey, Italy, Egypt, France, Belgium, and Ireland. He takes the hemp of Russia, Italy, Turkey and Hungary and New Zealand, and the best that India can grow. He uses cotton from the United States, Egypt, and India; jute from India; straw from Holland, Germany, and other countries; esparto from Spain, Algeria, Tunis—and Tripoli. These are the principal sources of fixed supply. But they do not suffice. The chemist has to be summoned to analyse unconsidered potentialities. And in the end he reports favourably on the straw of flax, on banana skins, bamboo, the dried stalk of the sugar-cane, on peat, on the waste hulls of cotton seed. The paper-maker goes back to Nature for inspiration. In her laboratory there is no such thing as waste, and he finds in waste products raw material for his trade, yielding greater treasure even than is hidden in all the tons of refuse containing radium, which were scattered on the dump-heaps of London in days when radium was unknown.

The Basis of a Library which is Formed in a Forest

But, so far, we have said nothing of the pulp of wood. That, to-day, is the great stand-by of the paper-maker. The giant of the forest, subdued by machinery, becomes a pulpy mass which the great mechanical wasp bleaches and beats and hardens and smooths and glazes until it issues from the machine in the form of paper, indistinguishable by any but an expert from paper that is made from cotton and linen rags.

At first sight it might perhaps appear that, with the forests of the world from which to cut, the paper-maker would have sure supplies for all time. That, however, is far from the fact. Only certain trees are of service for paper, and resources have to be carefully husbanded. For a number of years, the destruction of trees for pulp, among other purposes, has been so serious that the world has been brought within sight of a paper famine. So now the paper manufacturer, who was already an expert chemist and mechanical inventor, has turned forester. Instead of stripping forest land bare of trees, he cultivates his forest. He cuts down trees, but he plants others,

GREEN GRASS THAT BECOMES WHITE PAPER

THE ESPARTO GRASS, GROWN IN SPAIN AND NORTH AFRICA, FROM WHICH PAPER IS MADE

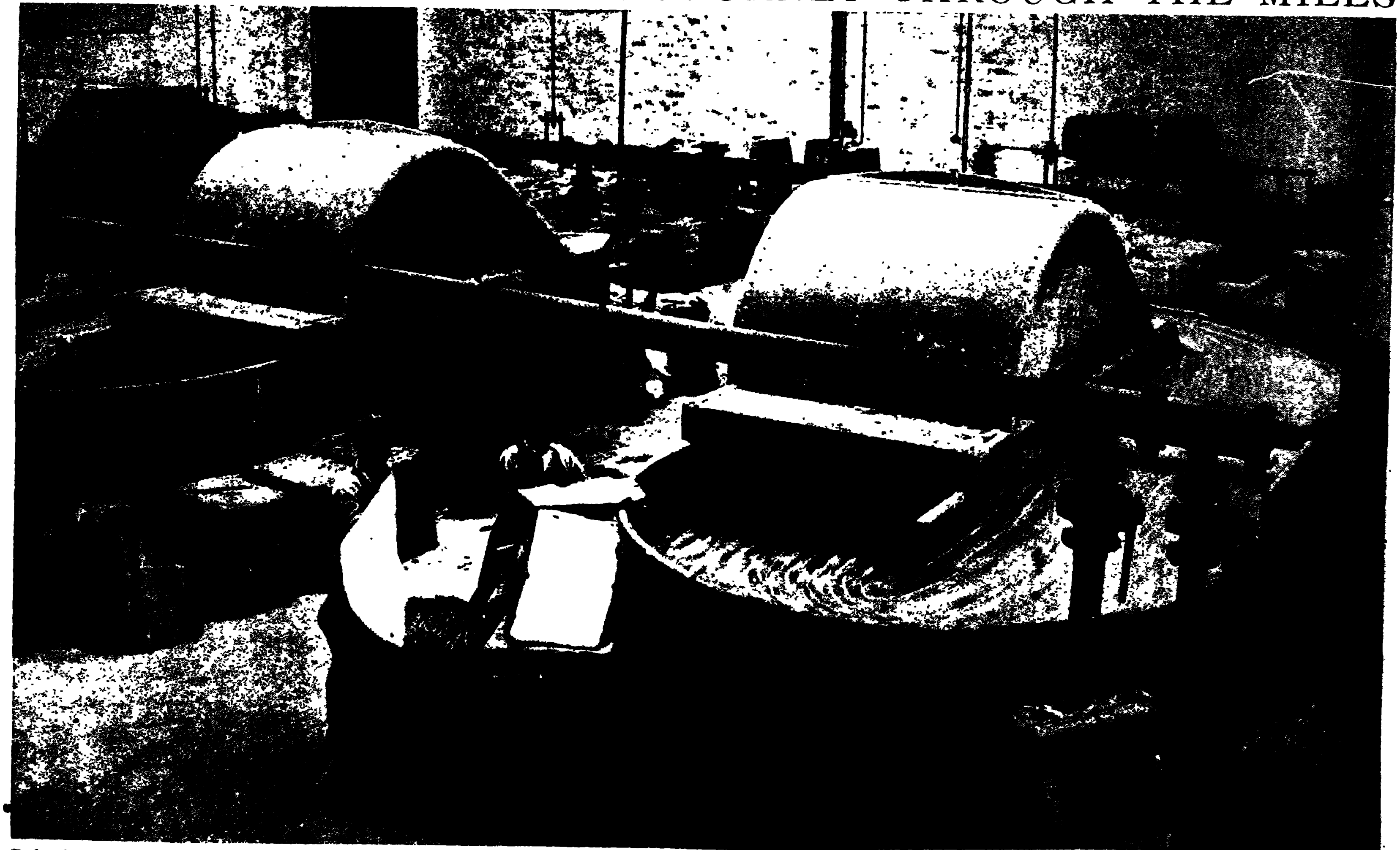
PUTTING THE GRASS INTO THE BOILER FOR PURIFICATION BEFORE MAKING IT INTO PAPER

Lacking an adequate supply of rags, the paper-maker had to seek substitutes, and the best he found was esparto grass, a product of Spain and North Africa. Here the grass is being made into paper.

GREEN MADE WHITE—THE ESPARTO GRASS IN THE BLEACHING TANK

After the esparto has been boiled under pressure for some hours it is removed to the bleaching tank, in which chemicals and water are added. The grass then undergoes a beating process. Other bleaching methods, carried out by machinery, are more economical, if less effective, than the manual.

THE PULP STARTS ON ITS JOURNEY THROUGH THE MILLS



Pulp, broken paper, and water are mixed in the breaker. Knives mounted on a heavy roller cut the pulp as it revolves, reducing it to fibres. In the breaker is a revolving drum covered with wire gauze provided with syphons, which drain out the dirty water and other impurities.

so that while he is thinning out his thousands of acres of tree-covered land, new growths are springing up in his footsteps. The paper forest of to-day, in the hands of the scientific paper-maker, is as carefully conserved as the rubber plantations called into being by the skill and care of man.

Having now examined the sources of the paper-maker's raw material, we may glance briefly, without penetrating into technical details, at the processes which convert that raw material into the finished article.

The Raw Material in its Early Stages at the Mill

We have three groups of substances—rags, wood-pulp, and grasses and other fibres. The rags, upon arriving at the mill, are freed from dirt, from buttons and all hard substances, and, to obtain the best results, cut by hand into strips about four inches square. As this is the more costly method, the cutting is generally done by machinery. The rags are sorted into various grades, next beaten and whirled in a revolving "duster," then boiled under pressure in revolving cylinders in a chemical solution which removes all colouring matter and renders the fibres flexible. The solvent used is, as a rule, caustic soda, which, by an ingenious process, is afterwards recovered from the water. Considerable care is required with the rags in this stage, as the strength of the alkaline solution in which they are immersed needs frequent modification.

The initial cleansing of the rags leads to the bleaching. This may be carried out by placing the rags for from eighteen to twenty-four hours in tanks of bleaching solution, after which they are lifted out, drained, and passed on to the breaking engine. But there are several methods, and this one, if sure, is slow and rather costly.

The Process by which Rags and Grass are Beaten and Made into Paper

All materials for paper-making need bleaching, and a modern installation includes a considerable bleaching plant—a series of towers, to each of which the substance passes in turn by mechanical action, to be compressed, bleached, washed, beaten into fibres, and turned out, ready for the machine, in quantities sufficient to yield sixty tons of paper a week. For present purposes we assume them to have been washed and bleached by the first process.

Following this preparation they are removed to a vessel called the "breaker." This is a vat, whose mechanism includes an iron roller fitted with knives, which pulp the rags into fibres. In this breaker the rags are caused to circulate for some hours. Clean water is from time to time introduced and the foul liquid withdrawn, so that the last vestiges of dirt disappear with the soda in which the first process had been accomplished. If bleaching is to be carried out in the breaker, the powder is introduced at this stage, and the "stuff," as it is now called, passes to the refiner, a modern machine in which a further clarifying is effected. Thence it is forced through pipes to the paper-making machine proper.

The treatment of esparto grass differs in its first stages from that to which rags are submitted. The end to be achieved is to resolve the grass into its fibres, free from all intercellular matter. It is placed in a peculiar type of boiler, where it rests upon a perforated false bottom. Through this the boiling liquor drains, to rise at the sides and be pumped as a spray upon the grass. By this means a constant circulation of moisture is maintained. The grass passes to the "potcher," which is similar in action to the "breaker," and here the esparto is broken into fibres of approximately even length. The grass is afterwards bleached and refined, and is in turn ready for the machine.

Two Kinds of Wood Pulp from which Paper is Made

The preparation of "stuff" from rags and esparto is carried on in British mills, but the wood pulp industry is confined to Norway and the New World, in which Newfoundland, our oldest colony, is the newest claimant to fame. Wood pulp is of two kinds—mechanical and chemical. Mechanical pulp, which is for the cheapest papers, consists simply of the trunks of trees ground to pulp, and containing all the substances of the original wood—the resin, gums, encrusting and intercellular matter. Chemical pulp consists of the fibre of the wood from which all foreign substances have been removed by chemical action. The first yields a cheaper but weaker paper than the second, and of course is not so enduring a fabric. Spruce, Scotch fir, aspen, and poplar are the trees to which the manufacturer chiefly has recourse. The trunks are cut into short logs, stripped of bark and knots, ground by machinery to chips, and then treated, either by a cheap and expeditious method, or by the more costly chemical process. After the mechanical pulp has been ground and boiled and beaten and bleached it comes out in thick strips resembling the "stuff" of cheap cardboard. The chemical is a more presentable product, to the paper-maker's eye, though the

difference in texture might not be specially obvious to the uninitiated observer.

Arrived at the mill, the pulp begins its career of transformation in the breaker. Here it is churned and beaten until it presents the appearance of an enormous cauldron of thick porridge. While it is in this stage, dye is added, if the paper is to be coloured. It follows the course of the rag-pulp—to the refiner, and, like that substance, is now ready for the machine, to which it is forced by way of a stout iron pipe.

The Machine in which a Running Stream Becomes a Roll of Paper

Properly mixed, the stuff leaves the breaker composed of five per cent. of fibre and ninety-five per cent. of water. It is to the eye at this stage merely a cloudy fluid; it leaves the machine at the opposite end as part of a roll of paper five miles long, wound upon a huge reel!

The machine by which the seeming miracle is wrought is one of the largest and most complex of all machines. That shown on page 598 is some 200 feet long. It works day and night, automatically feeding itself with pulp, and converting it into paper 142 inches wide, and at the rate of 500 feet an hour, twenty-four hours a day, with only a skilled man or two to look on.

Once the machine is started, the men attending it do nothing but wait lest an untoward something should turn up needing attention. The first time that the material is touched by hands after being thrown into the beaters is when men take it away on running pulleys in the form of completed rolls of paper, ready to be cut into narrower widths for the use of the insatiable presses in London and elsewhere.

The Moving Table of Wire which Carries a Stream of Flowing Paper

To describe this complicated process in detail would be beyond our province here, but one or two outstanding features of the progress from fluid to solid paper may be noted. Between the breaker and the machine comes the refiner, and a stuff-chest is also provided, serving, in the modern machine, only as a reserve supply in order that the machine may not be kept waiting should the refiner go amiss. From this point the stuff is forced to a mixing chest, where the proportions are modified to from half to one per cent. fibre and the rest water.

Should the refiners fail, the stuff-chests are the starting point of the mixture, but normally this comes direct from the refiners. In these the final purification has been undergone, though a straining process follows for the elimination of lumpy matter.

From here the stuff passes to what is known as the breast-box of the machine, from which it overflows on to a wide stretch of endless wire netting of very fine mesh, upon which it is carried at rates varying from 40 feet to 500 feet per minute, according to requirements. This moving table of wire cloth is cunningly contrived to impart a rocking motion, in imitation of the shake given manually in hand-made paper. But the force is graduated so that while the wire cloth is rather violently oscillated at the point nearest the wet end of the machine, the vibration dies away in the mechanism nearest the dry end of the machine.

The purpose of the oscillations is to make the fibres settle down and knit together. A large quantity of water passes from the stuff through the meshes of the wire cloth, to be collected in trays below and carried away by force pumps to a filter in which all vestiges of pulp are removed, leaving the water ready for further use.

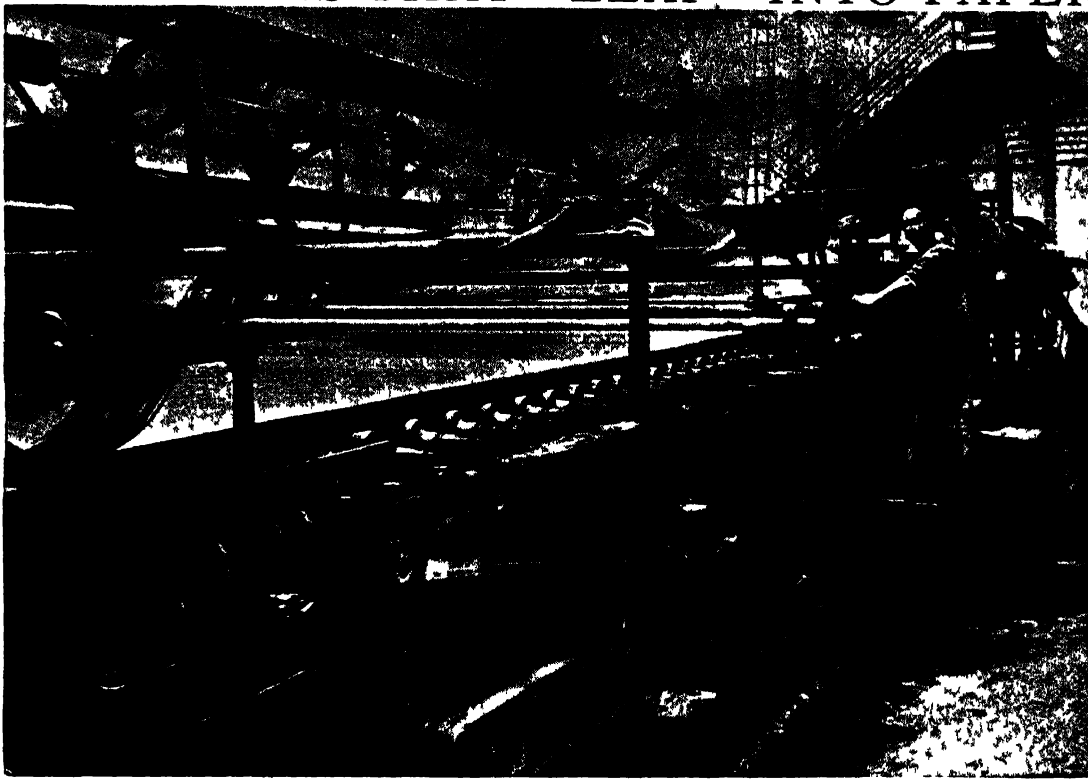
The Finishing of the Machine-made Paper and the Making of Paper by Hand

At the end of the wire cloth what may be described as fluid paper appears. The stream along the wire cloth thickens and becomes more and more opaque. It passes now over a series of suction boxes, each of which in turn extracts a quantity of moisture from the moving stream of coagulating fibres. In the case of paper which is to be water-marked, the operation is performed at this stage, a revolving cylinder bearing a design in wire making impressions upon the soft moist paper, much after the fashion of the stereotype plates upon the cylinders of a printing machine. But here, instead of making a surface impression, the watermark is pressed into the fabric itself. After passing the suction boxes the paper—for such in the rough it has now become—is conducted between a series of rollers covered with thick felt, which squeezes moisture from both faces in turn.

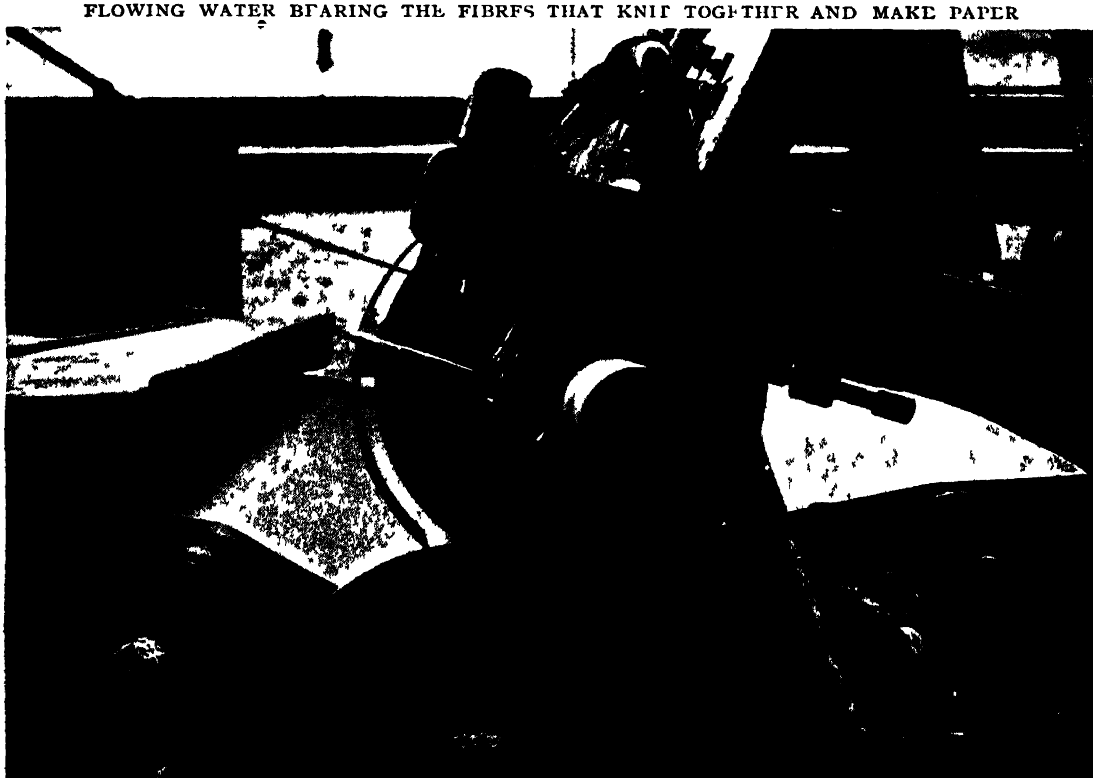
Next the paper is led round a complicated series of revolving cylinders which are heated with steam. These complete the drying process, and there remains only the "calendering," the passing of the paper between successive pairs of cylinders which impart an ink-resisting surface. There is needed then only the cutting of the paper into widths required by the printer.

In spite of the manifold wonders of the machine, hand-made paper is still the

THE FIBRES THAT "LEAP" INTO PAPER



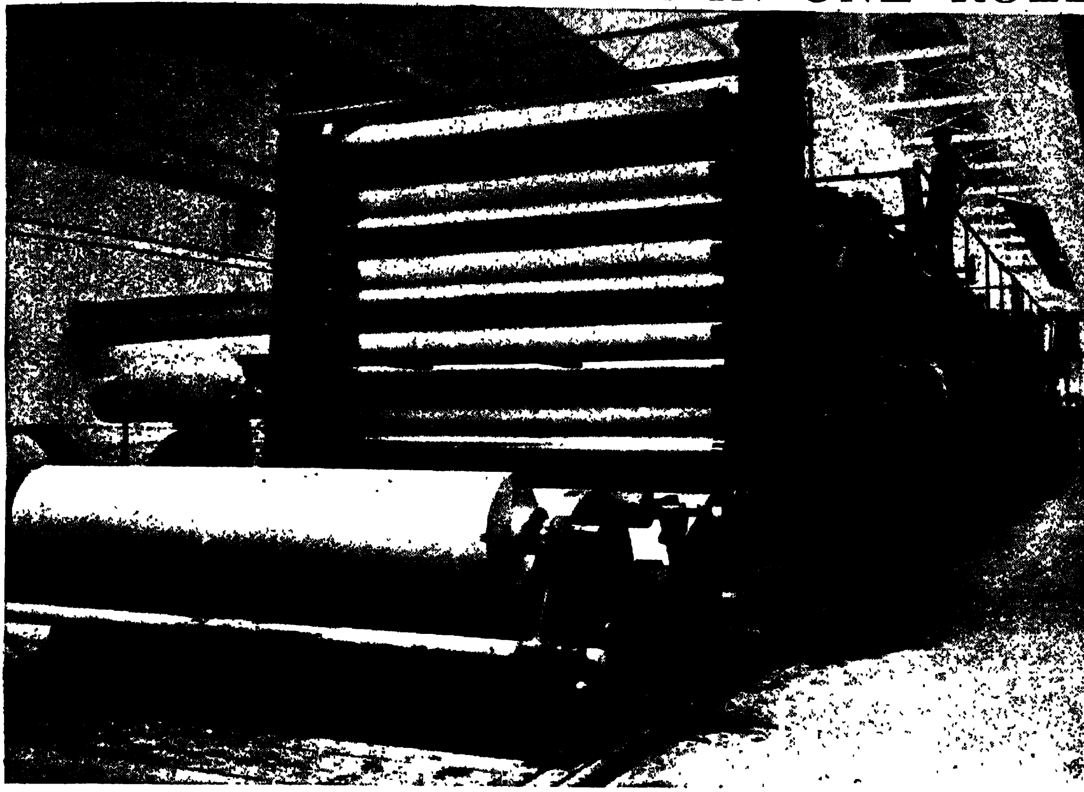
FLOWING WATER BEARING THE FIBRES THAT KNIT TOGETHER AND MAKE PAPER



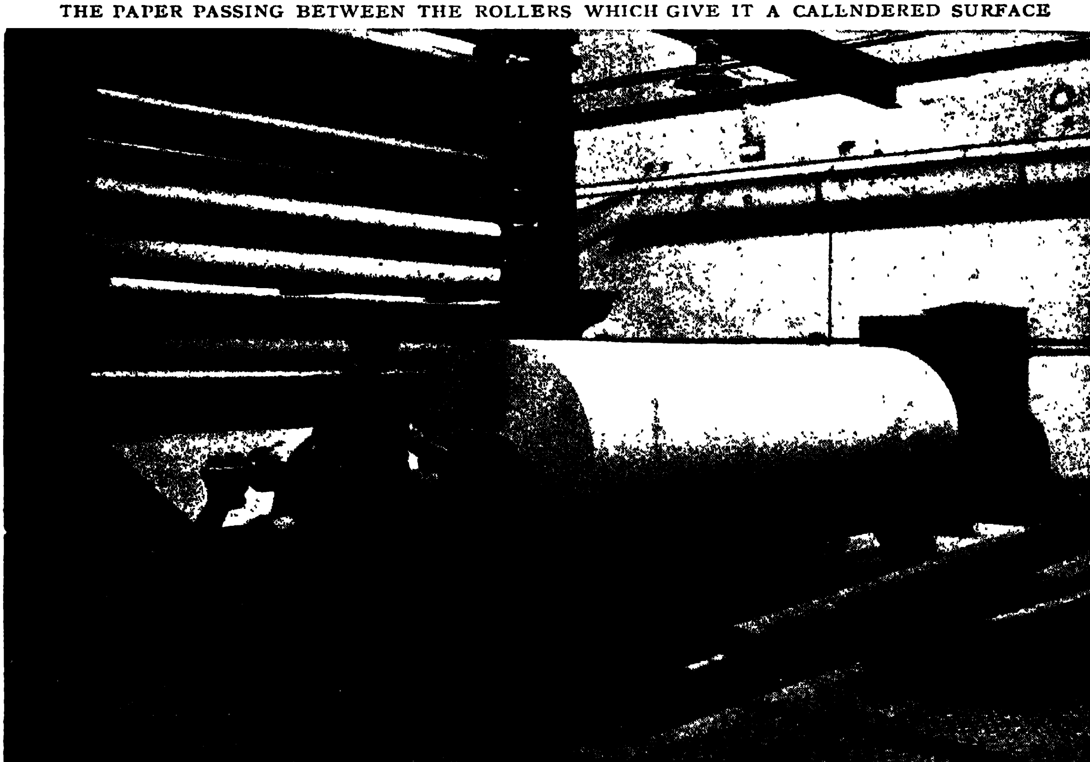
THE POINT AT WHICH THE FIBRES MAKE THEIR "LEAP" TO THE DRYING APPARATUS AS PAPER

After flowing in solution over the endless wire cloth, the fibres, losing moisture, make a leap, and suddenly form a sheet of damp paper, to be led round a maze of cylinders for pressing and drying.

FIVE MILES OF PAPER IN ONE ROLL



THE PAPER PASSING BETWEEN THE ROLLERS WHICH GIVE IT A CALENDERED SURFACE



THE PAPER COMES OFF THE MACHINE IN A REEL FIVE MILES LONG

The "stuff," now become paper, has passed from the beater, right along the machine, without once being touched by hand, and it is sent away by a travelling crane to be cut into the requisite widths.

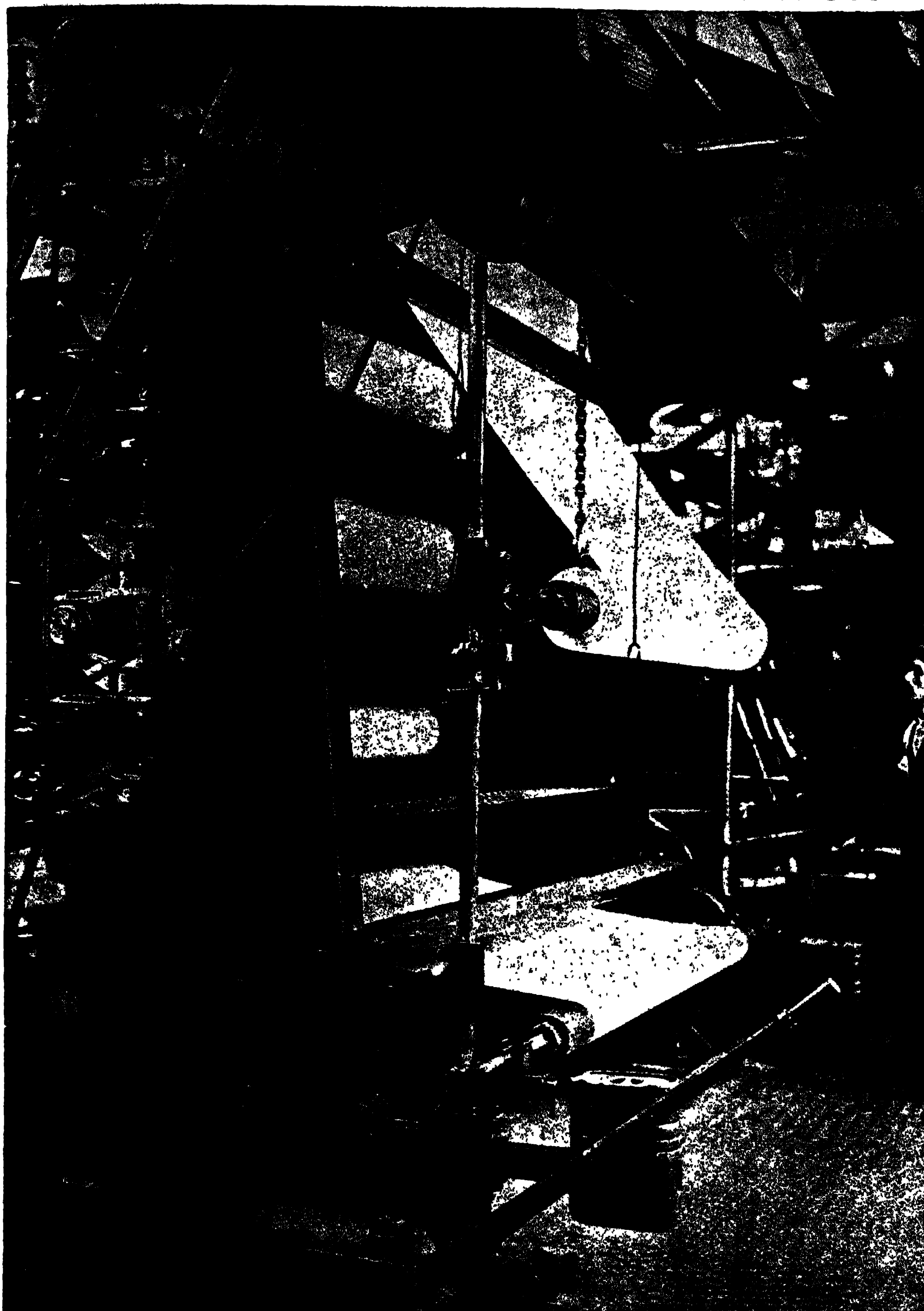
best, just as a hand-sewn boot is better than the product of the machine. The initial treatment of the rags—of which hand-made paper is exclusively formed—is the same as for machine pulp, up to the point at which the breaking and refining are completed. There the worker takes the fibres in hand, and, in place of the endless band of wire cloth, uses a hand frame of similar texture, which he can jerk and twist in such a manner as to make the fibres felt more satisfactorily than is possible by the automatic oscillations performed by the machine. While the pulp is on the wire cloth, the water-mark is impressed by a pattern in the wire slightly raised above the level of the rest of the surface. The pulp is transferred, after the necessary shaking and draining, to a sheet of felt, and with other sheets is pressed and dried, sized and calendered, ready for use.

It will be noticed that in surveying the machine at work we have taken account of only the cheaper form of paper, such as is used for newspapers. For papers requiring more "body" and a better surface, china clay and other substances are introduced into the stuff, and the paper undergoes a more extended calendering to give firmness combined with gloss.

But, enormous as are the demands upon the paper-maker for newspaper purposes, the industry embraces many makes of paper which never come in contact with a printing machine. The uses of paper are almost limitless. It can be made into a remarkably good imitation silk, into yarn, into sacking of an excellent type, into impermeable "canvas," into a perfect insulator for electric wires. In its last mentioned form paper plays a highly important part in making commercially possible the laying underground of the telegraph wires of the country. Cheaper than gutta-percha, which it supplants, it is so thin that a great number of wires can be perfectly insulated by paper in very small space. How strong the thinnest of papers can be made is shown by the remarkable tenacity of the banknote, and we have houses of paper, boats of paper, paper bottles, paper dinner-services, "straw" hats of the same substance; matches, artificial bricks for paving, piping for gas, cart-wheels, horseshoes, bicycle frames, gem-polishers, and half the requirements of the Japanese household, from window-frames to artificial leather and handkerchiefs—all of paper.

THE PAPYRUS PLANT, THE PAPER MATERIAL OF THE ANCIENT WORLD, GROWING IN EGYPT

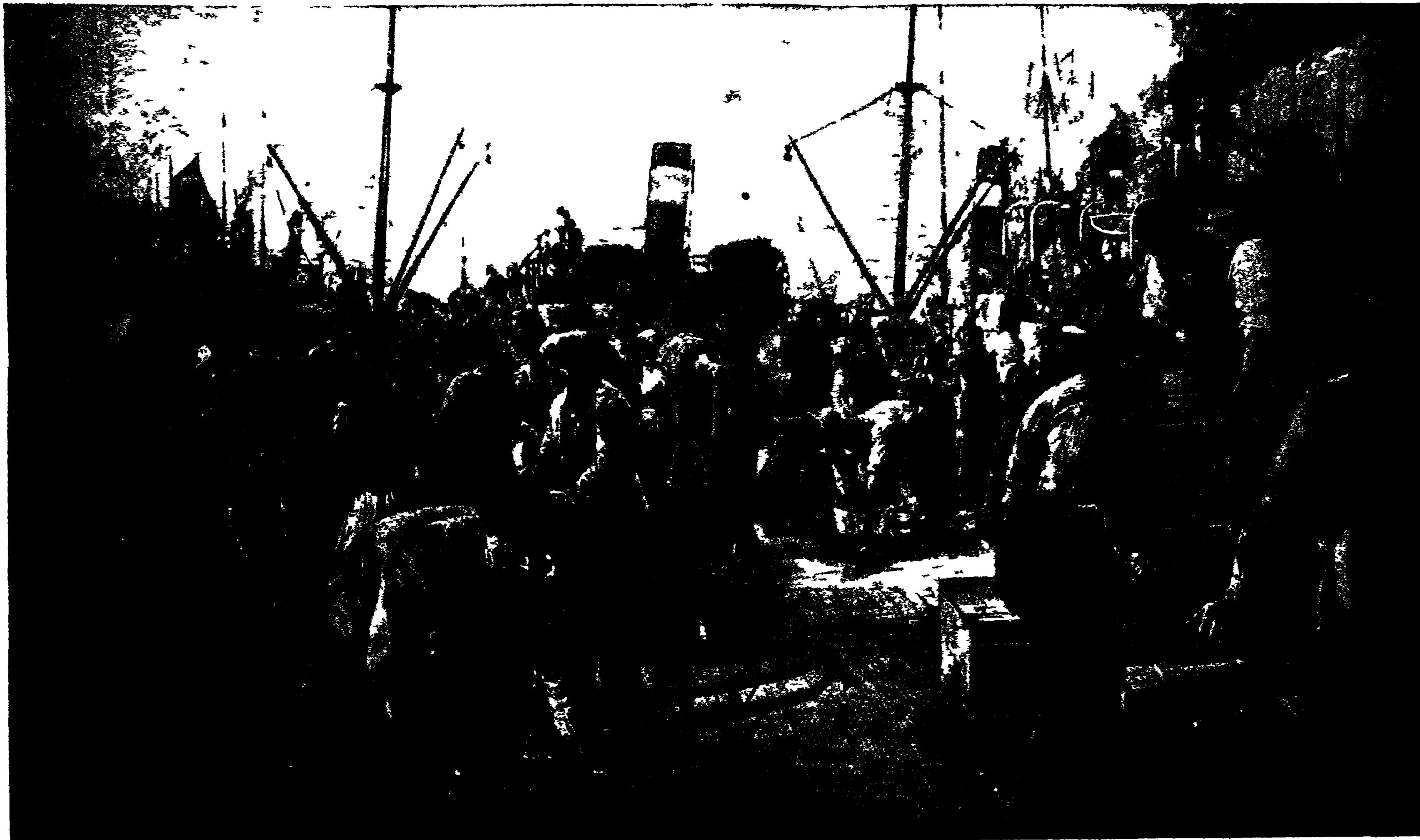
These startling applications of the paper-maker's art are of modern development, and the tale of the possibilities open to him is by no means exhausted. He has an unlimited market, but he has not an inexhaustible supply of raw material upon which to draw. A fire may ruin his forest, a drought may bring his mills to a standstill, imprudence may unduly impoverish his resources. The threat of a famine in pulp has made the paper-maker jealously treasure the forests upon which he has to depend. He cuts down, but he plants again. He thins out his forest and plants new trees in the place of old, so that "once a forest always a forest" has become his ideal in respect of the land whence his pulp is drawn. There has long been a cry for scientific forestry, and the exigencies of the paper trade have brought it into being.



PUTTING A GLAZE ON THE FINISHED PAPER BY PASSING IT BETWEEN MANY ROLLERS

For high-class paper on which photographic reproductions appear, a process known as super-calendering is necessary, and this picture shows the process. It is an elaboration of the calendering done by the paper-making machine, but involves the use of special materials in the make of the paper.

THE PORT OF HAMBURG, THE CENTRE-POINT OF THE WORLD-COMMERCE OF GERMANY



Hamburg, the free port of Germany, is one of the busiest marts in the world, where products from all parts of the earth are exchanged. Hamburg is, indeed, the largest seaport on the Continent, and the third in the world, coming after London and New York. It has the greatest coffee market of any nation.

THE THREE GREAT POWERS

The Tremendous Share of the World's Commerce Controlled by the United Kingdom, Germany, and the United States

THE GREAT TRIUMVIRATE OF INDUSTRY

THREE nations stand out pre-eminently in the world of trade, the United Kingdom, the German Empire, and the United States of America. Between them they share an incredibly large proportion of the world's commerce, own most of the world's ships, smelt most of the world's iron, build most of the world's railways, furnish nearly all the world's machinery, produce the greater part of the world's machine-made articles, and possess among their citizens most of the world's millionaires.

The people of each of these three pre-eminent industrial and commercial nations may be pardoned if they attribute the greatness and wealth of their own country entirely to the genius of their race. Few are the people who possess economic training, or who have given any considerable amount of thought to the causes which produce the wealth of some nations and the poverty of others. Very often, indeed, credit is given for commercial or industrial results to causes which are of quite minor importance, while the really important and basic factors are lost sight of.

In reviewing the wealth of the world as a whole, we saw how all-important is the possession of natural stores of energy, and in studying the economic position of the United Kingdom we found that, the largest and most useful form of stored energy being coal, and coal being so heavy and bulky as to make its transport costly, machine industry is chiefly carried on in coal areas. It follows that, if we take a geological map of the world, and ascertain the position of the world's coal areas, we know that we have—at least, if the coal areas are in the possession of white people—an infallible guide to the location of the world's industries. We have seen, too, that the United Kingdom, although lacking in so many desirable natural products, finds in her coal the means of drawing to her shores no small part of the wealth of the world.

When we turn to the rest of the world and inquire for other great coal-producing nations *we find them limited to two, the United States and Germany.*

The United States is the greatest of these—the greatest in the world. When we realise how enormous and how rich are the American coal-fields we wonder anew at the folly of the old-time British statesmen who sought to prevent their North American colony—the greatest coal area in the world—from manufacturing, and to restrict her citizens to being hewers of wood and drawers of water for the Mother Country.

As many as twenty-seven of the forty-seven states and territories of the United States contain coal which can be worked on a commercial basis, and this is true also of Alaska. We have to realise that the United States coalfields are thirty times as great as our own, and that, so far from it being cause for surprise that since 1899 the American coal production has exceeded our own, it is rather surprising that America did not take the lead at an earlier date. It is probable that the coalfields of the northern half of the American Continent at one time covered the whole of Central North America, from the Atlantic to the Rocky Mountains, and from Newfoundland to the Gulf of Mexico. Denudation is supposed to have removed large portions, but what remains constitutes the most magnificent store of natural energy known to the world.

First in importance come the mines of Pennsylvania, and this state has always been the first in the production of both anthracite and bituminous coal. The mines of Pennsylvania are part of the great line of coalfields running with the Appalachian Mountains, and are, perhaps, not merely the richest in America, but the richest in

the world. Of anthracite alone the Pennsylvanian mines are now equal to producing a hundred million tons a year in addition to a further hundred million tons of bituminous coal. Thus one single State of the Union approaches in output the entire production of either the United Kingdom or the German Empire, a fact which speaks volumes for the economic advantages which the United States of America naturally enjoys.

Illinois comes next in importance, her mines, as at present developed, being capable of producing over fifty million tons a year. From Illinois coal is transported to Chicago as well as to St. Louis and other inland cities. West Virginia is third, having coal so easily got that the price at the pit's mouth is but a few shillings a ton. Much Virginian coal is sent eastward, and a large part of it goes to market via the Ohio River. Fourth in order comes the State of Ohio, which is only less rich than Virginia.

These four states, Pennsylvania, Illinois, West Virginia, and Ohio, produce more than three-fourths of the entire United States output of coal, but if the mineral wealth of the remaining twenty-three coal states is small relatively, it is great actually.

The United States and its Wealth of Coal Beyond the Dreams of Avarice

Alabama produces as much coal as all Canada; Indiana as much as all Australia; Kentucky and Kansas together as much as India; Wyoming and Missouri together a much as all South Africa; while the remaining states have productions which several coal-less European nations would rejoice to possess. To recite the bare statistics of the United States Geological Survey, setting out the area of the American coalfields, is to the economist to picture "wealth beyond the dreams of avarice."

THE COALFIELDS OF THE UNITED STATES

Area and Nature of Coal	Square miles
ANTHRACITE COAL	500
BITUMINOUS COAL	
Triassic Field..	1,070
Appalachian Field	70,807
Northern Field	11,300
Central Field	58,000
Western Field	94,076
Rocky Mountains	100,110
Pacific Coast..	1,050
GRAND TOTAL OF SQUARE MILES ..	336,913

Thus, the United States coalfields have a total area—exclusive of the Alaskan mines—of nearly three times the entire area of the whole United Kingdom. Pennsylvania alone has a coal area as great as that of all the British coalfields. But this comparison, striking and significant as it is, gives no idea of the superiority of the United States' coal resources. Far-seeing men long ago pointed out to the world the inevitable consequence of the possession of such power. Consider the Pittsburg coal seam. It consists of a great sheet of coal about six feet thick, fifty miles long, and fifty miles wide.

Ten Thousand Million Tons of Coal in One Seam Near the Surface

After sixty years' depletion it is estimated to contain ten thousand million tons of commercial coal. Still one of the most important considerations is left to state. It is that this wonderful seam of coal is near the surface, and therefore easily and cheaply worked. At few points is it necessary to sink shafts. Most of the bituminous coal mines of Pennsylvania are quarried rather than mined.

So that the United States has not merely a great coal area, but a rich coal area; and not merely a rich coal area, but a coal area the most available, and therefore yielding the cheapest coal in the world. Given such natural wealth, even a dull people might become a rich people; and no one has accused the extraordinary medley of enterprising persons of all races which inhabits the United States of either dulness or incapacity.

The German Empire, the third in the great triumvirate of Coal Powers, is also exceedingly rich in fuel, but her resources approach more nearly to those of Britain than to those of the United States. The coal wealth of Germany was neither understood nor developed until recent years. So true is this, that while well-informed writers, basing themselves upon known facts, two generations ago predicted a brilliant future for American trade, the latent powers of what is now the German Empire were hardly suspected, and even denied.

A German Coalfield Covering Over a Thousand Square Miles

Thus we find even Jevons, the first economist who understood the coal question, writing in 1865 that "Prussia . . . is incapable of taking any considerable share of the trade of the world." Jevons did not know that Germany possessed in the districts of Upper Silesia, the Ruhr, and the Saar some of the most important coalfields of the world.

The chief German coalfield is that of the Ruhr, or of the Lower Rhine and Westphalia. The coal area here is over one

thousand square miles in extent. The number of seams is large, and there are more than sixty together representing a sheet of coal fifty to sixty yards thick. This field alone is estimated to contain 45,000 million tons. Even more wonderful are the Saarbrucken coal-beds in the Rhine Province, where there are more than two hundred seams one above another, the coal of which, if placed together without the intervening shales and sandstones, would be nearly four hundred feet thick. Many of these seams, however, cannot be worked profitably. The other German coalfields are also of great importance, if not so rich as that of Westphalia.

In addition to coal proper, Germany is also rich in lignite, or brown coal, which is found in Silesia, Saxony, Posen, Brunswick, Thuringia, and Hesse. It is only in the last twenty years that German lignite has been worked on an extensive scale. Lignite has not the heating power of coal, and it was only when German enterprise and science discovered how to make the lignite into briquettes, so that it could be economically transported, that it came into extensive industrial use. Three tons of manufactured lignite are equal to about two tons of coal, and even the briquette process would not make the material economical but for the fact that the German lignite seams are so exceedingly rich and so easily worked. Around Cologne, for example, the lignite lies in a seam varying from sixty to three hundred feet thick, with only some thirty to forty-five feet of matter above it. The lignite can thus be quarried cheaply, and the lignite briquettes sold at so low a price as to make it a competitor of coal in spite of its inferior caloric power.

Estimates of Germany's coal at available depths vary greatly, and range up to as much as four hundred thousand million tons, which is, of course, very much more than the highest estimate for the United Kingdom. There seems little doubt that the German coal resources are superior in quantity, if not in situation, to those of the United Kingdom. The peculiarity of the British coalfields is that they have been placed by Nature so close to tide-water. Germany, whose coal lies so much more inland, is not able to compete with the United Kingdom on level terms as an exporter of coal for maritime purposes, although she has seriously entered the export market in this respect.

It is difficult to make a precise comparison of the three Powers in respect of their coal supply, but in 1904 Simmersbach made the following estimate.

COAL OF THE THREE CHIEF NATIONS

United States	.. ..	681,000,000,000 tons
German Empire	..	415,300,000,000 tons
United Kingdom	..	193,000,000,000 tons

Simmersbach here used for the United Kingdom the estimate of the 1871 Royal Commission on Coal, but it should be observed that the last Royal Commission on the Coal Supplies (1905) estimated the United Kingdom coal resources at a total of 145,600 million tons, only 101,000 million of these being in proved fields under 4,000 feet deep. It may be that the German figures are also estimated liberally in the above table, but there is little doubt as to the larger content of the German fields. There is no doubt at all that the United States of America has much greater and richer power supplies than Britain and Germany put together, as the table at the foot of this page clearly shows.

When we come to coal production, as distinguished from coal possession, the element of uncertainty disappears. We know that until recently the latent power supplies of Germany and America have been developed so rapidly that the coal production of the United Kingdom has been altogether

THE WORLD'S COAL OUTPUT AND THE SHARE PRODUCED BY EACH OF THE THREE CHIEF COAL NATIONS

COUNTRY	1900 Tons	1900 Percentage of Total	1907 Tons	1907 Percentage of Total	1909 Tons (The figures are not quite complete)	1909 Percentage of Total
UNITED STATES	241,000,000	31·9	429,000,000	39·2	390,000,000	36·8
UNITED KINGDOM	225,000 000	29·8	268,000,000	24·5	264,000,000	24·8
GERMAN EMPIRE	147,000,000	19·5	202,000,000	18·4	214,000,000	20·2
TOTAL OF THREE NATIONS	613,000,000	81·2	899,000,000	82·1	868,000,000	81·8
REST OF THE WORLD, INCLUDING BRITISH POSSESSIONS	141,000,000	18·8	196,000,000	17·9	193,000,000	18·2
TOTAL FOR ALL THE WORLD	754,000,000	100·0	1,095,000,000	100·0	1,061,000,000	100·0

outdistanced by that of the United States, and approached by that of Germany.

We are now in a position to appreciate the governing factors of the industry and trade of the world. In the table on page 617 we give a simple statement of the world's coal output, distinguishing the contributions of the United States, the United Kingdom, and the German Empire. The latest year for which complete figures are available is 1909. Those of 1910 will be greater than those of 1909, and more nearly resemble those of 1907, which was a year of exceedingly good trade in all parts of the world. The table also shows the coal production in 1900 in order to illustrate what we have before referred to—the unprecedented rapidity of the development of trade in recent years.

The Three Nations which Produce Eight out of every Ten Tons of Coal in the World

It will be seen that in each of the years reviewed, 1900 and 1907 being boom trade years, and 1909 a year of good trade, *the three leading commercial nations produced over eight out of every ten tons of coal produced by all the world.* It is an astonishing and a dominating fact. We see that all the rest of the world—all Europe except Britain and Germany, all Asia, the whole of the American continent except the United States, all Africa, and all Australasia—produced in 1909 only 193,000,000 tons of coal, or less than one-half the production of a single country, the United States. At the present time the United States is producing about forty per cent. of the whole world's coal output, the United Kingdom is producing rather less than one-fourth, and the German Empire is producing about one-fifth.

Since 1900 the yearly output of the world has increased by over 300 million tons, but about 250 million tons of this increase is the share of the three leaders. In view of this overwhelming superiority in the power without which modern machines cannot be run economically, the supremacy of Britain, America, and Germany in industry and commerce is seen to be practically inevitable, given the habitation of the three countries by white men.

The Differences in the Price of Coal at the Pit's Mouth

One very important comparison remains to be made in this connection. We have seen how important it is, not merely to have coal, but to have coal which can be mined cheaply. Let us see what has happened in regard to the cost of getting coal in the three great power countries. The following are the latest figures showing the cost of coal at the pit's mouth.

PRICE OF A TON OF COAL AT THE PIT

Year	United Kingdom	United States	German Empire
	s. d.	s. d.	s. d.
1904	7 2	5 11	8 6
1905	6 11	5 8	8 8
1906	7 3	5 9	8 11
1907	9 0	5 11	9 9
1908	8 11	6 0	10 3

The comparison is very much in favour of the United States, as would be expected from our investigation of American coal resources. In recent years, while the cost of getting British and German coal has considerably increased, the cost of getting the more easily won American coal has been almost stationary. In 1908 British coal was nearly 3s. per ton, and German coal over 4s. per ton, dearer at the pit's mouth than American coal.

Moreover, a large part of the American output is anthracite, which is much dearer than bituminous coal. The cost of American bituminous coal at the pit's mouth is only about 4s. 6d. per ton, or about one-half the British and German figure. That is to say, Britain and Germany have a big handicap in the cost of getting indispensable power.

The Resources of the Three Great Nations in Minerals and Metals

If the figures were taken back to an earlier year, the contrast would be even more striking. Thirty years ago the three nations got their coal each at about the same cost. In thirty years the cost of getting United States coal has actually fallen, while the cost of getting British and German coal has greatly increased.

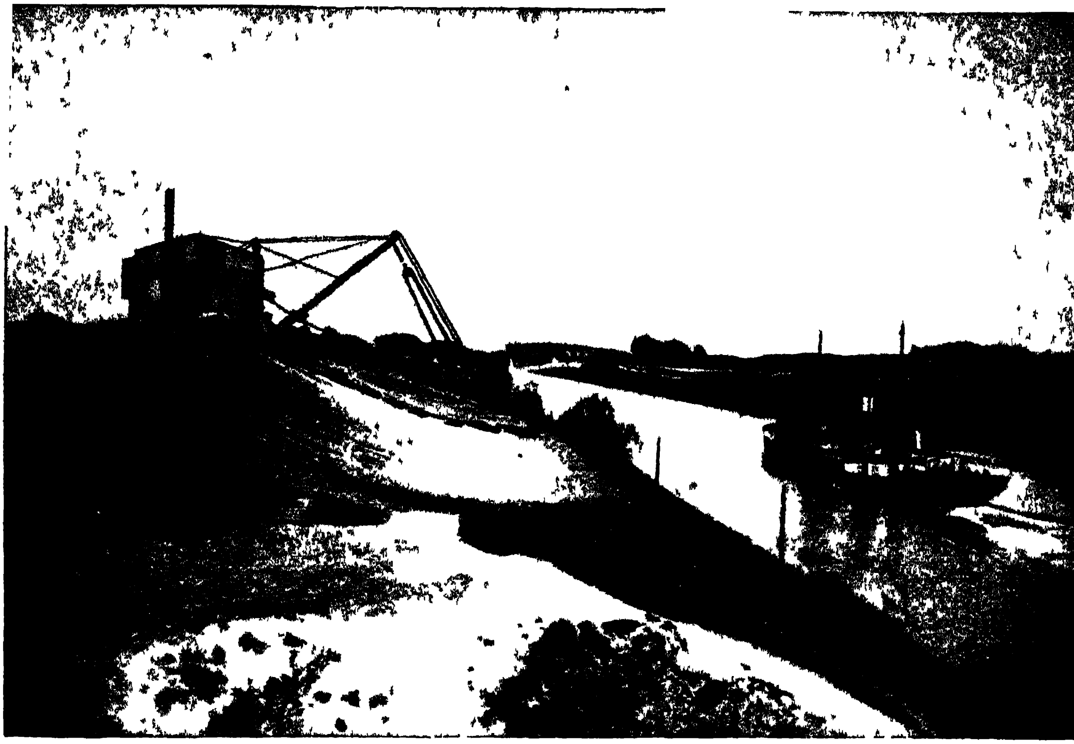
In mineral resources other than coal there is also a marked disparity in the position of the three coal powers. The poverty of the United Kingdom in respect of the metals has been already shown. In the table on page 620 we contrast it with the greater mineral resources of Germany, and with the enormously greater mineral resources of the United States.

Even more than in regard to coal, America leads the world in general mineral and metal resources. The figures are their own best commentary. It is impossible to exaggerate the economic advantages possessed by America and expressed in these eloquent statistics. It is not enough that she has in coal an infallible means of securing other materials even if she did not possess them.

THE THREE GREAT COAL NATIONS

THE COAL OUTPUT OF THE THREE GREATEST TRADING NATIONS COMPARED WITH THEIR TERRITORY

A year's output of coal in the United Kingdom is 264 million tons, in the United States 390 million tons, and in Germany 214 million tons Each truck in these drawings represent 20 million tons, and the coal areas are shown dark.



GERMANY'S FINE WATERWAYS—THE EXTENSION OF KAISER WILHELM CANAL NEAR LEVENSAU

She has within her own borders the world's best supplies of iron, of copper, of lead, and of that essence of coal, petroleum. The United States produces from her own native ores over forty per cent of the world's iron output. American copper is fifty per cent of the world's output. American zinc is one-fourth, American lead nearly one-third, American gold nearly one-fourth, and American silver over one-fourth of the world's output. American petroleum actually amounts to two-thirds of the world's output, a fact which will become of more than industrial importance if, as is probable, the ships and warships of the future are most economically and advantageously run with oil fuel. Germany, while ranking far below the United States in metal resources is seen to take high rank in respect of iron, zinc, and lead. In this connection it may be remarked that it was the English invention of the commercial manufacture of iron from phosphoric ores which enabled Germany to make effective use of her great native supply of that mineral. The table at the foot of this page gives the latest figures available.

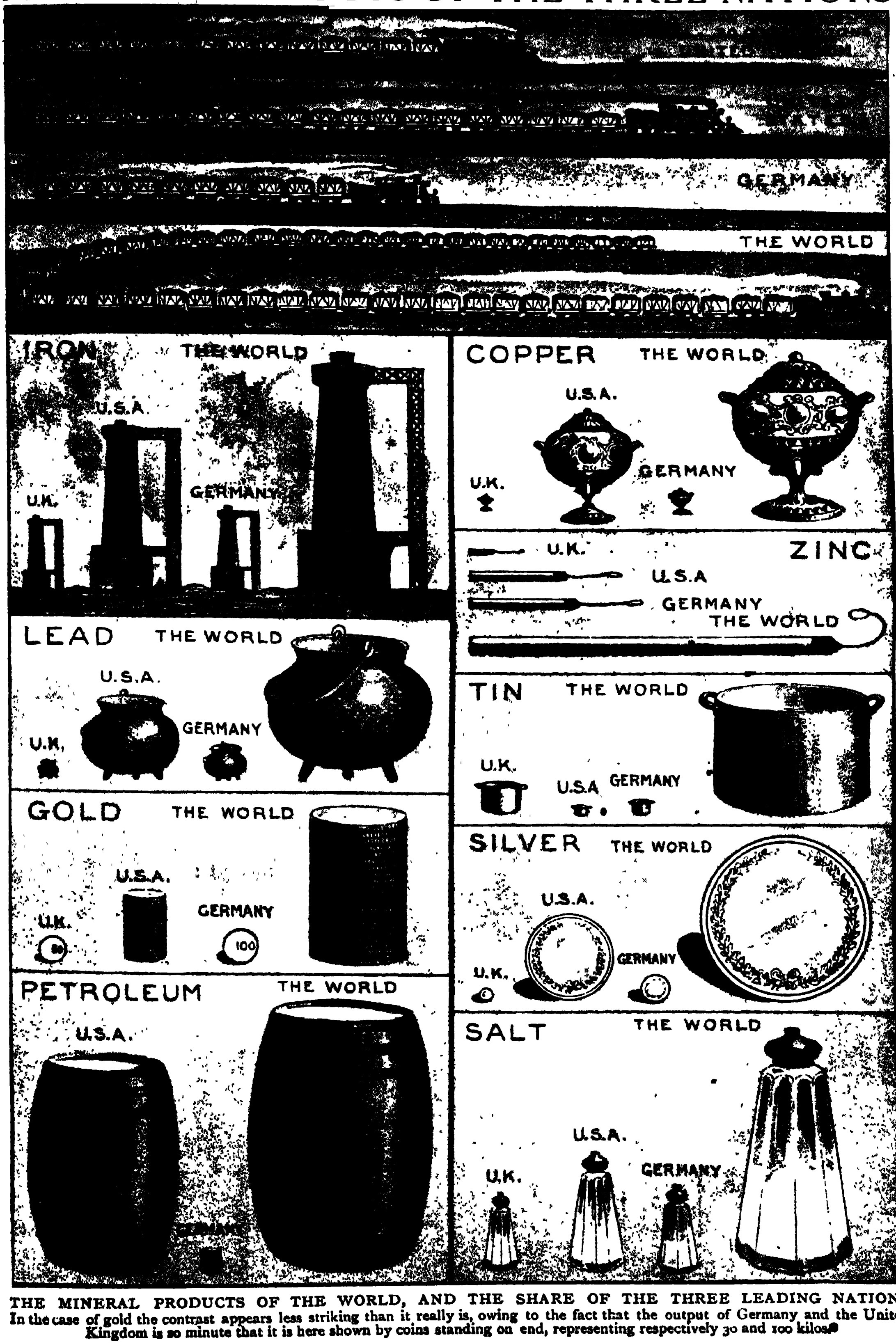
Turning from coal and iron to field and forest, from the clamour and bustle of the industrial centre to the peace and quietude of agricultural pursuits, we find that the world's trade leaders continue to present a remarkable contrast in point of their resources. The United Kingdom has 120,000

MINERAL AND METAL RESOURCES OF BRITAIN, AMERICA, AND GERMANY IN 1909

The output of minerals and metals contained in or obtained from ores raised in the countries named

MINERAL OR METAL	UNITED KINGDOM	UNITED STATES	GERMAN EMPIRE	ALL THE WORLD
Coal—Avoir Tons	264,000 000	390,000,000	214,000,000	1,061,000,000
Iron—Metric Tons ..	4,900,000	26,200 000	7 100,000	50,000,000
Copper—Metric Tons ..	500	496 000	25,000	863,000
Zinc—Metric Tons .	4,000	209,000	230,000	856,000
Lead—Metric Tons . .	23,000	321,000	89,000	1,050,000
Tin—Metric Tons .. .	5,300	10	20	117,000
Gold—Kilos	30	150,000	100	686,000
Silver—Kilos	4,400	1,700,000	166,000	6,340,000
Petroleum—Gallons	—	6,323,000,000	36,000,000	9,975,000,000
Salt—Metric Tons	1,900,000	3,800,000	2,000,000	17,200,000

MINERAL PRODUCTS OF THE THREE NATIONS



THE MINERAL PRODUCTS OF THE WORLD, AND THE SHARE OF THE THREE LEADING NATIONS
In the case of gold the contrast appears less striking than it really is, owing to the fact that the output of Germany and the United Kingdom is so minute that it is here shown by coins standing on end, representing respectively 30 and 100 kilos.

square miles of area, and 45,000,000 people, or 375 persons to each square mile. The German Empire has 209,000 square miles of area, and 65,000,000 people, or 311 persons to each square mile. The United States has 3,571,000 square miles of area, and 95,000,000 people, or only 26 persons to each square mile.

It follows that the United Kingdom has to obtain by commerce a considerable proportion of her food supply—probably about one-half of such foods as can be grown in her climate, in addition to many foods which she cannot grow at all from oversea. The German Empire has increasingly to import food as her population rapidly grows, while the United States of America is, for all practical purposes, able to feed all her people, and for the present, at any rate, to furnish a considerable surplus of food for export.

The United Kingdom wheatfields produce about 60,000,000 bushels of wheat per annum; in addition, we find it necessary to import about 240,000,000 bushels of wheat for our daily bread.

The Home Growth of Food in Germany and the United States

The German Empire is rapidly becoming more dependent on her foreign trade for food. Her population is increasing at the rate of about 800,000 per annum, and her imports of food have shown increase in recent years. Indeed, at the present time Germany is importing food to the amount of £100,000,000 sterling per annum, which is the more remarkable because considerable import duties are imposed in order to make Germany as far as possible independent of foreign food.

The United States has been growing so rapidly in population that the world is no longer able to expect from her the large export of grain which America once put on the market. In the last thirty years the United States home consumption of wheat has doubled. At the same time wheat production has greatly increased, but not at so great a rate, and consequently exports are beginning to fall. Indeed, in 1904, with a large home consumption and a crop failure, the United States found herself with a margin of only about 40,000,000 bushels left for export. Since then the margin has again risen, but uncertainty exists as to how long an export surplus will be available. We shall have occasion to consider this important point thoroughly when we come to examine the problem of the world's food supplies.

The magnificent area and range of climate of the United States gives her in many other respects great economic advantages over her competitors. Britain and Germany alike have to look to the United States for their main supplies of cotton. So great is the American cotton monopoly that the American crop forms two-thirds of the world's entire production.

In her forests and fisheries the United States is equally fortunate, and if wanton exploitation has largely denuded her forest areas, America has awakened to the necessity of conservation, and drastic steps are now being taken to assure future plenty for the American timber trade.

America's Neglect of her Magnificent Seaboards and Germany's Yearning for the Sea

In one very important respect, however, the United States has largely failed to make use of her natural resources. She occupies a fine geographical position, fronting the two great oceans, and with her excellent harbours and the need to ship so many natural productions, it was to be expected that she would develop a magnificent mercantile marine. In practice she has not done this. Her shipping has been eclipsed, not only by the United Kingdom, but, as is even more remarkable, by that of Germany. The position of the German Empire in Central Europe gives her great advantages in European trade, which she takes full advantage of with her splendidly organised national railway system. She is not naturally a sea power, however, for even in the North Sea she is shut off by Belgium and Holland from the sea, for which she so naturally and so strongly yearns. Yet, in spite of this maritime handicap, Germany owns a mercantile marine which, while it is small as compared with that of the United Kingdom, is great when contrasted with the shipping which carries the Stars and Stripes in ocean trade—a mere million tons.

Germany's Creation of the Trade Facilities which Nature has Denied Her

It is impossible to believe, however, that the United States will be for ever content to neglect her mercantile marine. Possessing every advantage for shipping, from the materials of construction to well-situated ports, we may be well assured that the adequate development of American shipping is but a matter of time. The United States Government, by constructing the Panama Canal, is putting the final touch to America's splendid geographical position and shipping facilities. When the canal is opened, in 1915

or 1916, every part of the world will be easily accessible from both her seaboards, and it will be strange indeed if she does not make full use of the great opportunity which will be hers. Already, indeed, there is announced the formation of a great American steamship company to develop inter-oceanic communication and commerce.

Germany, in so many respects poorly favoured as compared with America, and in some respects even as compared with the United Kingdom, has, by a marvellous concentration upon essential matters, and by a power of scientific organisation which is justly the admiration of the world, created artificially the facilities for trade which Nature has denied her. The United Kingdom is a group of islands, with no part of its surface far from the sea or far from coal. The German Empire has a great and important industrial area largely removed from access to sea-borne commerce.

The Splendid Development of Canals and Railways in the German Empire

With admirable skill Germany has worked to abolish Nature's disabilities. She has improved her great rivers, and added to them a fine system of canals to cheapen transport. Simultaneously, her railways have been developed, not with a view to private interest or profit, but with sole regard for the furtherance of trade. Low railway rates and simplicity of charges upon the great German railway system have done much to atone for the fact that Germany has so little seaboard. Over her national lines goods pour in all directions, consigned to her neighbours in Europe, or to the Baltic and North Sea ports for export oversea. Transport is the life of trade; railways and canals are the land arteries of trade; and well has Germany been rewarded for the foresight and prudence which led her to attach national importance to the improvement and cheapening of means of transport.

Nevertheless, while giving all credit to Germany for the courage, determination, and ability which she has applied to industry and commerce, she could not have risen to her present high rank among trading nations if she had not possessed, in one of the few great available coal supplies of the world, a mainspring of work.

It is under present conditions an almost unassailable position which is occupied by the three great industrial States we have been examining. It is a position unapproachable because it is based upon forces with which man cannot at present contend. While the Coal Age lasts, the nations which possess coal will continue to enjoy a preferential position. It is not too much to say that so enormous is the natural advantage which these nations possess that it far outranges any possible unwisdom or folly of an economic character likely to be committed by their statesmen.

Indeed, the truth of this statement becomes readily apparent when we reflect that each of these three nations practises a very different economic policy, and yet each of them is triumphant in the world of trade.

The Relative Sources of Natural Power which Man can Never Alter

Man may, of course, modify, and modify considerably in some respects, the economic results of the possession of power supplies, but he cannot altogether obliterate them. A Briton or a German, if he disquiets himself with regard to the much larger stores of power possessed by the United States, disquiets himself in vain. It is possible for a race of men, by taking thought, to add an inch or two, if not a cubit, to its stature; it is not possible for a nation to add a single ton of fuel to her mines.

The duration of the Age of Coal is unknown to us, and therefore we cannot hazard a guess as to how long Britain, America, and Germany will continue to wield that Sceptre of Iron which is wrought with Coal. There is already trembling along the far-reaching lines of scientific investigation the possibility of control of power in such measure as to render the burning of fuel a clumsy and obsolete method of driving machinery. If ever this possibility is realised, it is probable that the realisation will find Power more widely and more evenly distributed about the globe. That would mean comparative loss to the three present trade leaders, but, it is important to observe, no more than that. It would, of course mean actual gain to them, gain in such measure as to make the loss of a comparative supremacy a thing of trifling and negligible importance.

If Adam Smith were Writing his "Wealth of Nations" To-day

In the meantime, coal is the chief determinant of wealth. Adam Smith wrote his "Wealth of Nations" before the use of coal was fully realised, but if Adam Smith were alive to-day to write his great work again, he would place the consideration of coal at the beginning of his book, for it is chiefly coal which, in the modern world, makes the material wealth of nations.

THE SUBTLE POWER A WOMAN HAS

SAMSON YIELDING TO THE ENTREATIES OF DELILAH AND LOSING HIS STRENGTH

THE BEAUTY OF THE QUEEN OF SHEBA, WHICH HELD CAPTIVE THE WISDOM OF SOLOMON

These pictures are from the famous Tissot collection of Bible paintings, and are reproduced here by courtesy of M. Brunoff.

THE MARRIAGE PROBLEM

Shallow Thinkers and Foolish Books which Would Destroy the Base of Modern Society

LIFE FROM THE CHILD'S POINT OF VIEW

MODERN society is developing into a very complex thing; and the more complex it becomes, the clearer and finer our power of vision must grow, if we are to retain any control over the tremendous structure we are building up. We need some simple and yet large test of the extraordinary variety of human achievements. Looking back at the nineteenth century, for instance, we cannot rest in the view taken by one of the acutest minds in modern literature, Matthew Arnold, and expressed by him in these well-known lines:

The epoch ends, the world is still.
The age has talked and worked its fill—
The famous orators have shone,
The famous poets have sung and gone,
The famous men of war have fought,
The famous speculators thought,
The famous players, sculptors, wrought,
The famous painters fill'd their wall,
The famous critics judged it all.
O'er that wide plain, now wrapt in gloom,
Where many a splendour finds its tomb—
Many spent fames and fallen mights—
The one or two immortal lights
Rise slowly up into the sky
To shine there everlastingly,
Like stars over the bounding hill—
The epoch ends, the world is still.

Here we have the historical view, in which everything is dead, dusty and docketed, and only a few names survive in the memories of man. To get the living scientific view we must turn to the living child, and look at things through its eyes. At the end of the dead epoch stands a baby, the inheritor of its sound traditions and good deeds, the victim of its mistakes and its sins.

It is marvellous how the perspective changes when we regard life and the great problems of life from the point of view of the child. At the close of the nineteenth century, for example, general attention was occupied, throughout the civilised world, by certain new problems of marriage. These problems were discussed in the church and on the stage, in the newspaper and in the popular novel; and at least one school of politicians attempted to make profit out of the apparently widespread discontent over some of the conditions of modern matrimony. At the present day the subject is still commonly discussed from the nineteenth century point of view. The man of science, however, has begun to look at the matter through the eyes of the child, and he has thus recovered the large and simple vision necessary in arriving at any clear conclusion.

Primarily and originally the function of marriage is to maintain the species; and it is here that modern literature so often conflicts with modern science. From the days when Ibsen, with his famous play "A Doll's House," opened the current discussion on the problems of marriage, nearly every playwright or novelist has assumed that men and women have the right to test their marriage entirely by the degree of pleasure that their union brings to each of them. If a wife has a husband who cannot appreciate her feelings for a more active and stirring life, it is her duty, Ibsen seems to have suggested, to slam the front door on her husband and children, and go out into the world of art or literature, business or politics. Another Scandinavian dramatist, Strindberg, has recently taken to advocating the husband's side of the case: he holds that marriage restricts the development of the more virile qualities of a man; the woman enslaves him and forces him to make all kinds of sacrifices for her pleasure. Mr. Bernard Shaw appears to adopt somewhat the same point of view

in his "Man and Superman." As Mr. Rudyard Kipling put it, in the days when he was young and cleverly foolish—

Down to Gehenna, or up to the Throne,
He travels fastest who travels alone.

Ibsen and Strindberg present the selfish point of view, and it is just possible that in what both of them say there is a small measure of truth.

Having erected, in modern civilised society, so apparently complete a series of defences against the harsher forces of Nature, we are sometimes tempted to think that we have entirely escaped from the laws of life. In regard to marriage, we are often inclined to regard the personal happiness of the married couple as the function of their union. Human marriage is, no doubt, at its best a pure and noble source of joy, but it is this indirectly rather than directly. When we take the happiness of two married people as the supreme and only test of the success of their marriage, we are putting the cart before the horse. We are mistaking one of the means for the crowning end; and when we do this, there is considerable danger of our going so far as to stop half way down the road that Nature meant us to follow to the finish. Happiness in marriage is like a double hedge of rose-bushes along the path of life: it sweetens the journey and makes it pleasant and attractive, but we must not continually stray to pluck every flower we pass.

The Men and Women who are too Selfish to Hand Down the Torch of Life

To put it in another way, happiness in marriage is like the reward a good workman receives for undertaking a difficult duty. But, in regard to the maintenance of the species, the care and the trouble and the expense of looking after the young must be undertaken even where no material reward is forthcoming. Happiness is not *necessary*, as many self-sacrificing women have proved by bringing up their children in an admirable way, in spite of the fact that their own married lives have been unhappy. Ibsen and Strindberg and their followers do not mean well when they point out the limitations of marriage; their cynicism is based on a love of pleasure and a dislike of the duties of married life. But in so far as their criticisms serve to bring out the fact that marriage is fellow-service and the joys of fellow-service, rather than a refined form of selfishness, they help to clear away a mist of romantic falsities, and assist us in seeing the problem in a clear light. Let us for the moment, and for argument's sake, be willing to admit that modern marriage is a failure. Certainly the number of those who are able to set up for themselves in life is growing, while the number of those who undertake the highest duties of the race seems diminishing.

This is the veritable problem of modern marriage. The growth of luxury is spreading among our people a base and narrow selfishness. Our literary pedants put it that marriage prevents men and women from developing their individuality and cultivating their finer powers to the uttermost. More ordinary cynics say that it would hinder them in their career and make them less successful in life. So the individual *apparently* enjoys more luxury, and the race decays. He owes his existence to the sacrifices of his ancestors, but he is too selfish to hand down the torch of life.

The Great Empires of the Past which Forgot their Children

Some of the most splendid civilisations have failed because the interests of the child were overlooked in the pursuit of apparently other high aims. The achievements of the ancient Greeks, for example, are, from an historical point of view, of very great importance; but the intellectual, artistic, and political triumphs of Grecian civilisation in the days of its supreme power must have seemed of little importance when looked at through the eyes of Grecian children a few hundred years afterwards. The welfare of the race had been neglected, and so the glory of Greece passed away like a pageant of sunset clouds. If, in the struggle for the dominion of the world, the children of the Romans had been also lost sight of, the civilisation of Greece, which the Romans adopted and handed down, might to a large extent have been lost to humanity. In course of time, Rome also became too busy to look after her children, with the result that a good deal of her work would not have survived if the Teutonic and Mohammedan races had not retained the simpler and more important view of the function of human life.

The Seeds of Ancient Destruction at Work in the Modern World

For nearly fifteen hundred years the nations with their ancient seat in Northern Europe have carried on the work of civilisation, and at the same time kept in view the interests of the child. By these two means they have spread over a large part of the earth, and advanced in a wonderful manner the power and knowledge of man. Now, however, they seem to be going the way of Greece and Rome. Under the present conditions of civilised society, where any capable

man and woman can, by devoting the whole of their energy to the task of making money and enjoying the pleasures of money, live in comfortable singleness all their lives without exciting the scorn of their neighbours, marriage may be regarded as a failure—if examined entirely from an individual selfish point of view. Sheer self-regarding prudence of this sort is at present not uncommon ; it extends in every nation with the growth of luxury, and it was one of the chief causes of the downfall of the most brilliant civilisations of the past.

Great poets and novelists celebrate the love that leads to marriage. What they do from the instinct of genius, the great thinkers do from the larger reason. For they see that the individual must be subordinated to the needs of society. But little modern realists, studying life from a personal standpoint only, manage to express the ideas of an ignoble crowd of modern men and women who have lost their natural instinct and failed to arrive at the larger reason for its existence. Happily, all fine things in life are unreasonable from a self-centred point of view - heroism and self-sacrifice, as well as love and marriage ; and perhaps if we study marriage from a scientific point of view, without confusing the pleasures of luxury with the joys of parenthood, we shall find that it is not a failure. Self-development and self-assertion cease to be hostile forces when each self is seeking the fulfilment of its own purposes and its fullest development, in a common end—whether that end be married life or some other. As for marriage preventing a man from making a career—as is so often foolishly said—the contrary is the general case. For every man whose finer life has been crushed by the needs of his wife and children, a hundred thousand have been stimulated to a higher level of industry and efficiency. The lone wolf is a good fighter when pinched by hunger, but the wolf with starving cubs to feed is as fierce as death. So it is with men. They work their hardest and their best when they are not working for themselves ; and from their highest efforts not only the family but the nation benefits. And now let us go on with the study of marriage from the point at which its modern critic leaves it.

THE STICKLEBACK GUARDING ITS YOUNG

The brave little stickleback builds a nest for its young in the bed a river or a pond, and guards them from enemies.

Nature has not always ruled that the union of the sexes should be a long and high source of pleasure to the parents. The interests of the offspring are supreme. Among several of the lowest forms of life, sometimes a mother and sometimes a father is sacrificed in the interests of the species. When the cochineal insect, for instance, is about to bring forth young, it dies, leaving the shell of its body as a protective envelope for its offspring. Thus, while in one sense the welfare of a species depends upon the welfare of its individuals, in another sense the welfare of the species entails some sacrifice of the welfare of its individuals.

Among many of the lowest forms of life the greater part of the burden falls upon the young, which perish in immense numbers. A codfish produces above a million eggs, and survives to do this year after year. But while the life of the parent is preserved, nine hundred and ninety-nine thousand and more of the progeny die before maturity. Even among fishes, however, we find the burden of maintaining the species more fairly divided between the parents and the offspring. The parents build nests for their young, and, like the brave little stickleback, watch over them and guard them. As a rule, the need for parental care increases at every step upward in the scale of life. Either the mother or the father—and often both—must devote an increasing amount of time and care to bringing up the young and defending them from creatures of prey. Thus from an intensely selfish point of view marriage is a failure even among the animals.

Nature, however, is generous to the poor beasts of the field who faithfully undertake the duties imposed upon them. The longer the period they give up to the care of a

single brood, the longer becomes the period in which they are able to live for their own sake. In the highest class of animals, the mammals. regarded as a whole, we see a general advance in this conciliation of the interests of the race, the parents and the young. We see it also within the class itself on ascending from its lower to its higher types. For example, a small rodent arrives at full growth in a few months, and, after producing large and frequent broods, it soon dies. There is but a short early period during which the female lives for herself; and as she usually loses life before she is past her prime, she enjoys no latter days unburdened by offspring. Turning to the other extreme, among the mammals, we find an immense contrast. From twenty to thirty years of the life of a young elephant are passed entirely in personal development and activity. Offspring are produced in few numbers and at long intervals, and the tax of bearing them thus falls lightly on the adult female, while the male throughout his very long life is scarcely inconvenienced.

The System that is Best Morally is Most Efficient Scientifically

Long ago Herbert Spencer pointed out that the domestic relations which are reckoned the highest from a moral standpoint will be found to be those most efficient in a scientific view. It is this inspiring coincidence which we must now trace. In a former chapter we dealt with the relations of the sexes chiefly in regard to their bearing on the conditions of the men and women who entered into them. Keeping to the ordinary outlook, we indicated the steps by means of which the mothers and fathers of the race were benefited as they advanced from irregular unions to permanent marriages of one man with one wife. This, however, was rather a superficial survey. In the end it is the child who witnesses to the value of the marriage from which he is born. Here the happiness of the parents does not count, except in so far as it has a direct bearing on the welfare of the offspring. It is only the actual way in which the parents have carried out their duties that tells on the child and makes him the living testimony of their qualities.

Beginning with the effects of promiscuous unions, we need not turn, unhappily, to savage races or to barbaric times to find in the child a victim of all that is worst in human nature. The utter negation of parenthood is seen in the foundlings of our great cities; they are the most pitiable and the most appalling evidences of an age of pleasure-seeking cowardice. At the present day the Foundling Hospital, established by Captain Coram in 1739 "to suppress the inhuman custom of exposing new-born infants to perish in the streets," receives every year about five times the number of applications that it is able to grant.

The "Children of the Fatherland" Denied by their Parents

In the eighteenth century, when the Government ordered this single hospital to admit all children offered, 14,934 foundlings were received in four years, of whom only 4400 lived to be put out as apprentices. The total expense was £500,000. Each child of the State that grew to manhood thus cost the nation about £114. Nowadays, most of the work of rescuing children deserted by their parents is undertaken by charitable institutions, such as Dr. Barnardo's Homes and the Ragged School Union; and many cases are dealt with under our very bad Poor Law system. Little distinction is made between the poor abandoned waif and children who have been orphaned by the death of their parents; and so it is difficult to ascertain the actual number of real foundlings in our rich, busy, and highly civilised community. In France, where wealth is more equally distributed, the "children of the fatherland," as they are prettily called, are said to number about 150,000, but here again it is possible that natural orphans are included among the victims of human vice and selfishness.

Still, it is clear that some of the lowest of the brutes are, by the supreme test of natural selection, creatures superior to many civilised men and women. Mitigate as we will the harsher forms of the struggle for existence, yet all our social co-operation and achievements are vain and idle if we neglect the duties of parenthood.

Where an Uneducated Peasantry Keeps in Advance of the Better Instructed Races

One of the most damaging facts in the vital statistics for Europe is that the lowest proportion of illegitimate births is found in illiterate regions, such as Russia, Ireland, and Brittany; while in countries where elementary education is common the proportion of illegitimate children is high. For instance, in the Scandinavian and Germanic lands, where the literature of the modern revolt against the duties of marriage began and spread, sometimes one child in every ten is born out of wedlock. Here are the last figures, showing the illegitimate

children per thousand births in various countries, dating between the years 1900 and 1905.

Denmark	101
Sweden	113
Norway	74
Austria	141
Germany	84
France	88
Scotland	64
England	40
Ireland	26
Russia	27

These figures, of course, are not always an index to the morality of the various countries, but they bring out our point that education and prosperity seem to make for irregular relations of the sexes.

The Weakening of the Belief in Marriage in the United States

It is possible that England is an exception to this rule, perhaps the old leaven of Puritanism saves us, but more probably the Anglo-Saxon race generally is misusing its old powers of self-control for the individual end of personal comfort and personal success in regard to the business side of life.

However this may be, we have only to turn to the second great branch of the Anglo-Saxon race in order to study the subtlest and perhaps the deadliest form of irregular unions. No doubt the American has the same respect for legal morality as the Englishman. He, too, has much of the Puritan in him, and he, too, has the same trick of holding to the forms of his traditions while disobeying the spirit of them. As Professor W. F. Willcox, the chief statistician of the United States Census, recently remarked, the belief in marriage as an institution lasting till death became weakened in the United States during the nineteenth century, along with the weakening of other religious conceptions. It has yet to be determined, Professor Willcox goes on to say, whether a substitute for the religious idea of marriage can be developed under the influence of any utilitarian forces.

The Selfish Philosophy which is Working Against the Future of America

At present it seems as though the Americans are not very anxious to find a substitute—if such a thing exists. They have discovered in marriage and divorce a simple and legal form of promiscuity which they use with extraordinary zest. Every year the number of American divorces is about double that for the whole of the rest of the Christian world.

The large space given in our newspapers to reports on divorce cases is, fortunately, very misleading. Many persons are apt to conclude that a considerable proportion of English marriages are utter failures. But the last figures available show that there were only 844 divorces in England in 1905. It is true that in 1858 there were only 326, but the increase in forty-seven years is not remarkable when compared with the increase in the population. The figures are, indeed, very reassuring when compared with those of the United States. In 1906 there were over 72,000 divorces in the nation founded by the Pilgrim Fathers; and this loosening of the marriage bond is accompanied by a great diminution in the birth-rate of the native white population, which is now notorious. "Blessed are the meek," said Christ, "for they shall inherit the earth." The self-assertive Yankee, bent wholly on personal aggrandisement, will probably vanish in the next two hundred years, and the poor humble emigrants from Southern Europe will possess his territories—unless they, too, in turn become smitten with the passion for greed and pleasure and power. Thus natural selection in its severest form is seen to be still working inside all those defences of civilisation which man thinks he has erected against Nature.

The Happy Distinction of England Contrasted with America

Professor Willcox seems to find a sad consolation in the theory that the middle classes of America are only the first to strike down the path to destruction, and that all the peoples of Europe are following them, some slowly, some quickly. The general looseness of the marriage bond in the United States, he thinks, is the outcome of a tendency which has been at work in Europe since the Reformation. In his view, it is poverty and lack of facilities which hinder all the other races of Christendom from combining marriage and divorce into a common system. If this were so, we could only say of the lower and middle classes of Europe—as Thomas Gray said of the English peasantry in the eighteenth century—that their want of power and money was happy, in that it restricted their power of doing ill, so that "their sober wishes never learnt to stray." But we are not inclined to agree with Professor Willcox that the tendency in Europe is to follow the United States in making the marriage bond easily dissolvable. Perhaps the ancient ties of home life in Europe are stronger; perhaps the European mother is readier to suffer in silence for the sake of her children. However this may be, there is the significant fact that about fifty times as many

divorces occur among a given number of Americans—excluding negroes—as take place among the same given number of Englishmen. The difference would be very much higher if there were also excluded from the American estimate the many millions of European immigrants and their children who hold to the sound traditions of marriage which they brought with them from the Old World.

The marriage-and-divorce system at its worst is promiscuity; in its more usual and moderate form it is a reversion to polygamy in the ancient Christian sense of that word. In its ordinary meaning, human polygamy is restricted to a marriage of one man to several women. It was so rare and so extraordinary for a woman to have several husbands that the term polyandry was invented for this stranger form of union. In the marriage-and-divorce system, however, we have got back to the stage in which many savages and most of the animals remain. Male and female during their lives enter into transitory unions with the opposite sex, changing their partners several times. This is a kind of successive polygamy, and as such we can contrast it with the simultaneous polygamy of the savage and barbaric races.

No doubt if polygamy again became a general practice it could be made to consist with a fairly high form of civilisation, provided that it did not lead, as it now does, to a terribly diminished birth-rate. Ordinary barbaric polygamy has at least this in its favour: that it does not seem greatly to decrease the number of children. Without allowing that polygamy is naturally produced and maintained by the loss of men in war, we may admit that, when two races are continually in conflict, the one that does not utilise all its women as mothers will be unable to hold its ground against the other which does. Then, in a barbaric community formed partly of wifeless men, of men with one wife each, and men who have more than one, this last class is usually superior. Among savages, it is composed of the stronger and more courageous warriors; among semi-civilised people, it is made up of the men who are generally the more capable. In both cases these men will leave a larger number of offspring than the other men; and it is probable that their children will, on the whole, be remarkable for their inherited strength of body and powers of mind. Such seem to be the natural advantages of barbaric polygamy.

THE DENIAL OF PARENTAL RESPONSIBILITY—"THE FOUNDLING" BY HENRY HENSHALL

The Foundling Hospital in London, established in 1739 "to suppress the inhuman custom of exposing new-born infants to perish in the streets," receives every year about five times as many applications as it can grant.

Its gravest disadvantage is that it produces a child of a lower type than the monogamous marriage. The woman, of course, suffers as well, even where the mothers have separate households. She is deprived of the continual esteem and loving care which make the life of the singly married woman pleasant and inspiring. Naturally, there are jealousies and quarrels in a polygamous family—the mind and character and soul of the woman cannot fully develop. This tells on the training of her children, and they, of course, suffer also from a too diffused paternal care.

The Effect of the Marriage System on Competition between Peoples

Thus, when other things are equal, a polygamous nation goes down before a monogamous people, whose men have been better disciplined and better instructed generally. This is seen not only in trial by battle, but in every form of human competition. No doubt the great modern polygamous races do not practise polygamy on a large scale; it is only their chief men who can afford to have many wives. It is, however, on these chief men and their children that there falls the task of directing the policy, the civilisation, and the industrial expansion of the country. Against them are ranged men brought up in the higher school of single marriage. That is why, for the last three thousand years, victory has generally inclined at last to the side of the more monogamous nations.

Even the advantages of barbaric polygamy disappear in the marriage-and-divorce system, which we are told will spread from America to Europe. Here it is only more unstable, restless, and pleasure-loving spirits who make and break their unions. The change of partners entails the destruction of the home life; that is to say, the children bear the entire cost of the divorce. They are in a worse case than the offspring of the barbaric polygamist, who have at least a permanent home, even if they lack the full parental care necessary to bring out their finest qualities.

The Unhappy Lot of Hundreds of Thousands of American Children

The children of the marriage-and-divorce system—there are hundreds of thousands of them now in the United States—are worse off than the foundling. They grow up usually without the moral training that even a waif obtains in an institution.

This fact is indeed so apparent, even to many men and women who have adopted the marriage-and-divorce system, that they often send the children at an early age away from the half-emptied home; and an American writer, describing New York, says that the home is passing away, and that in future the school must be the world of the child, whether working, learning, or playing.

Here we again arrive, from the point of view of the child, at another argument in favour of a single and permanent marriage. Some of the clearest thinkers in the advanced Socialistic school are inclined to favour the marriage-and-divorce system. They justly observe that it makes for the breaking up of all home life, and prepares the way for the State to take over the entire care of the children. But it is a notorious fact that "institution children" are much slower in developing than children brought up with their parents; and there is, besides, a tendency among them for the somewhat troublesome qualities of initiative, enterprise, and individuality to be repressed, for the sake of the less valuable qualities which go with discipline and routine. It is because a stable home life helps to bring out in many ways the uniqueness and personality of a child that a marriage lasting for life between one man and one woman is the highest form of union from a moral point of view, and from a scientific standpoint the best means of maintaining the species.

A Possible Explanation of the Decline in Inventive Genius of America

With each advance in our knowledge and power, modern civilisation becomes easier to maintain in one way, and more difficult to build up in another way. Less routine and manual work is required, as the number and capabilities of our iron slaves increase; our machines, in war and industry alike, perform every year a still larger part of the machine-like labours of society. Every year we need more originality of mind and more virility of character in the men who invent and shape and direct our iron slaves. In other words, we want urgently more of those qualities which permanent single marriages are most likely to possess.

Some of the best minds of America are now vainly seeking for an explanation of the deplorable fact that their countrymen generally are losing the inventive talents for which, only twenty years ago, they were famous throughout the earth. If, as we think, the explanation is partly to be found in the results of the marriage-and-divorce system on the new generation of native Americans, it is clear that by adopting that system the rest of Christendom would pass away like ancient Greece and Rome.

THE SPLENDID MANHOOD OF FRANCE DRIVEN OUT BY RELIGIOUS PERSECUTION

The sins of a nation are visited upon the future. The France of to-day is the historical consequence of two tremendous racial disasters—the expulsion of the Huguenots and the Napoleonic wars. In the case of the Huguenots, France's loss was England's gain; many of the persecuted Protestants driven from their own country, as shown in this fine picture by Mr. Sheridan Knowles, came across the Channel to enrich the industrial life of England.

THE THING THAT MATTERS

The Astounding Discovery that Nations are Made up of Men, and that the Foundations of Empires are Alive

THERE IS NO WEALTH BUT LIFE

We have seen enough already to prove that numbers count in human affairs. The law of population-pressure and the elementary facts of birth and death rates suffice to convince us. But the Eugenist is the last person, obviously, who must permit himself to commit the error of supposing that numbers are everything, for he persistently denies that the numbers stand for the same thing in any two cases; and, further, the argument from numbers alone is notoriously contrary to the facts of history, which has been made by people like the Greeks and Jews and Romans and English, conspicuously few in numbers throughout their entire record, compared with the huge masses of human population, scarcely remembered even by name, upon which, or in spite of which, they did their work.

We are thus faced with the old controversy, now somewhat wearisome to those who dislike half-truths, between the advocates of numbers and the advocates of the select and few. The controversy is disappointing, because we clearly have to reckon, in human affairs, both with quantity and quality, and because the aim of eugenics is the most of the best people—which obviously includes both ideas. But, beyond question, the Eugenist must put human quality first in his estimation, as we appraise other noble and beautiful things, such as poetry or pictures, and thereafter he must seek to obtain as much as possible of the quality which he admires.

In a noble and never-to-be-forgotten passage, Ruskin taught the so-called political economists of his day that "There is no wealth but life." But since life may be of many qualities—from the criminal to the saint, the idiot to the genius, the paralytic to the athlete, and so forth—it is evident that the statement requires qualification, according to the quality of life. Ruskin added this qualification, in many great passages, too little read by many who profess and call themselves Eugenists. Not only is there wealth, there is also *illth*, as Ruskin pointed out; and whether we are studying the individual or the nation, this tremendous distinction requires to be made. Assuming for the present, then, what may hereafter be evident, that for a nation, as for an individual, there is no wealth but life, and that every society, state, or empire is built upon living foundations, the quality of which depends, from generation to generation, upon the quality of the national parenthood, let us survey some of the great events and problems of history and population, from this point of view, beginning with ancient Greece, which produced the immortal Eugenist Plato, and ending with the problem of our "Sister Isle," whose destiny, *under whatever legislative scheme*, will be determined by the quality first, and quantity second, of its men and women, and by those alone.

History is full of the rise and fall of races and civilisations. The archæologists are now teaching us that pre-history is composed of the same tragedies; and though we know nothing of the causes which produced them in prehistoric times, we do know that they were ultimately biological—that the breed of men must have failed, for some reason or other. Within the historic era we have some record of Greece, Rome, Spain, France, Russia, and Ireland, which may serve to show how strong is the eugenic case from the historic point of view. But before we take these up in their order, we must meet one ancient argument which was applied by the Greeks to the disappearance of races before their time, and has since been applied to the Greeks in their turn, and to the other historic instances of decadence since the Grecian age. The argument has found

a champion in the person of no less conspicuous a thinker than Mr. Arthur Balfour, as recently as in his Sidgwick Lecture on "Decadence" in 1908.

This is the argument that races naturally and inevitably grow old, as individuals do. It is an admirable instance of the danger of what is called the "argument from analogy," a favourite method of Plato and Aristotle, to whom first we owe this idea about races. The argument from analogy asserts that because two things are similar in one or more points, they are similar in all. Races—or societies—and individuals are similar in many points, and therefore in all. Just, then, as the individual is mortal—runs this argument—so is the race. Each has its period of youth and growth, its maturity, and finally its decadence, senility, and death.

On the contrary, the science of life declares, as the capital fact which contrasts the individual and the race, that while the individual is naturally mortal, so far as "this mortal life" is concerned, the race is naturally immortal. The tendency of life is not to die, but to live. If individuals die, that is because more life and fuller is thus attained than if life bodied itself in immortal forms—they die for the immortal race.

"And the Individual Withers and the World is More and More"

But the germ-plasm is immortal; it has no inherent tendency either to degenerate or to die. Species exist and flourish now which are millions of years older than mankind. "The individual withers, the race is more and more."

The reply of the biologist to this theory of Plato's is, therefore, that the theory denies the one essential fact in virtue of which the individual is only the individual, and the race is the race—the one is made to pass, the other to remain. This fallacy of racial senility is nevertheless always cropping up, notwithstanding its evidently absurd character, and notwithstanding the positive evidence furnished by the countless races, animal and vegetable, which are known to have persisted for unthinkable ages. Doubtless races can be killed, for the germ-plasm, though naturally immortal, is not invulnerable; but it is one thing to assert that races die because they must, and another to assert that they die because they are killed.

With this ancient error put wholly aside, let us survey, in chronological order, the historic tragedies already named, from the standpoint already provided, if he will use it, for the historian to-day by what we have already described as the foundations of eugenics. And first as to Greece.

The fall of incomparable Greece, not after four thousand years, as in the case of Babylon, nor after such a long life as Rome enjoyed, has been the subject of the historian's wonder and comment ever since. Modern eugenics makes the deliberate suggestion that, in this case and in the others which resemble it, historians have been competent to describe, but never to explain, because they did not make their survey from the standpoint which the foundations of eugenics provide.

Was the Fall of Greece Due to Race-Poisoning by Malaria?

Historians have never agreed about Greece, as they have never agreed about Rome. But a historian of the new school, Mr. W. H. S. Jones, published in 1907 a notable little book which offers an explanation of Greek decadence based upon the malarial studies of Sir Ronald Ross.

In brief, the conclusion is that the introduction of malaria into Greece caused the decadence of the population by racial poisoning; and this conclusion is obviously to be based on two lines of argument. First, we seem to find evidence showing that malaria was unknown in Greece during the great age. The disease has exceedingly striking features, and there is no word of anything like it in the authors of the time. Further, no malarious population—and there are many examples to study at the present day—could begin to display the characteristics of the Greeks in the great age. But then it would appear that malaria was introduced, probably as the result of military campaigns, and spread rapidly through the people, as its custom is when it gets the chance. Second, we have evidence of the present day, showing that the children of malarious persons are defective in development and in energy, and have the marks of a degenerate population as compared with their immediate ancestors.

A Fundamental Error often Made by the Historians

We know that malaria is a chronic disease, involving the production of poisons in the blood; and that these poisons must be carried to the germ-plasm and germ-cells of future parents. This is the argument of Sir Ronald Ross; and it is on the strength of the strong evidence which he adduces, that the present writer has included malaria in the list of "racial poisons." The theory, then, is that the fall of Greece was due to malarial race-poisoning.

The students of this subject are somewhat inclined to believe that malaria may also have played a part in the decadence of Rome, which we must now consider.

Here, again, we find the popular explanation, beloved of historians, to be a biological one; and again the biologist is bound to reply that what the historian assumes does not happen. The historian assumes that the characteristics of mind and body which people acquire in their own lives are transmitted to their offspring. This has nothing to do with the exhaustively proved fact of the action of poisons in the parental body upon the germ-plasm contained in it. No; it is the theory that, say, the son of the trained musician or linguist will have a special aptitude for music or language, not because his father had this aptitude, which would be a good argument, but because the father trained it, which is a bad argument.

This transmission of characteristics acquired by the parents is supposed to apply to such a case as Rome. The people, being too successful, are supposed to become idle and luxurious and unenterprising, and these characteristics, acquired by them, are supposed to become native in their children.

The Reason Why the Quality of the Life of Rome Fell

On the other hand, the same argument serves historians for the explanation of the building up of races. Thus they suppose that for many generations a race is disciplined, and so at last there is produced a race with discipline in its very bone; or for many generations a nation makes adventure upon the sea, and so at last appears a generation of predestined sailors with blue water in its blood.

Obviously such a theory of heredity may be of any service he will to the historian; but the transmission which it assumes does not occur, and therefore we must abandon this facile and highly adaptable argument, upon which so many volumes have been written. The view commonly credited to Weismann, but first advanced by Galton, that these modifications of parental habit and character are not reproduced in offspring, is now accepted. If there are no other factors of racial degeneration, races make a fresh start in each generation—apart from the possible operation of the racial poisons—and Rome fell without the quality of the Roman breed falling. But "every wise man's son doth know" better than that. The quality of the Roman breed *did* fall, and we must find out, if we can, the reason why. Here, again, the new view is based upon scientific considerations, though in this case they are not derived from the study of disease, but from Darwin's theory of selection. Was there any cause at work in Rome whereby the more valuable members of each generation were rejected, and the less valuable selected, for parenthood? It is argued by Prof. David Starr Jordan, a distinguished American biologist, that there was.

The Recruiting-sergeant who Brought Rome Down to the Ground

Along the far-flung Roman frontiers there was always need for soldiers. Some "little war" was constantly in progress, and Roman youth was required accordingly. Whom should the recruiting-sergeants want but the healthy, strong, brave, enduring? And whom should they reject but the diseased, weakly, puny, and easily tired? We cannot doubt the answer; and we must remember that those whom the recruiters rejected for military service they therefore selected for parental service. They practically said to the second-rate: "You are not good enough to be a Roman soldier; stay at home, and be a Roman father!" Was it not the children of such fathers who wanted nothing but bread and games?

Such, in outline, is Dr. Jordan's argument—that Rome fell because "reversed selection" spoilt the breed. This is not the only case in which we shall find that war has acted in this fashion—destroying the physically superior, and leaving the race to be maintained by the physically inferior. The argument is plain enough, but we had to wait for recent times, and for the influence of the great science of life in its application to the life of man, before so deep-cutting a theory could be applied to this old historical problem. Here the argument is simply stated. Let it not be supposed that we are arguing this to be the sole cause of the decline of Rome; for doubtless many causes were at work, and reversed selection among fathers must not have more than its due share of weight allotted to it.

A Decline in the Standard of Motherhood which Undermined the Foundations of Rome

Solomon's assertion that "Righteousness exalteth a nation" may be taken literally and strictly in its application to sexual and parental morality. We know that in declining Rome the moral standard fell, marriage was dishonoured, the use of drugs designed against the next generation was in large favour, and the standard of motherhood declined; while the cry went up that there was a shortage of soldiers of Roman blood for the legions. A Roman writer,

THE BLOW WHICH STRUCK DOWN A NATION FROM WITHIN—THE INQUISITION & THE FALL OF SPAIN

ONE OF THE GREAT ANTI-EUGENIC FORCES IN HISTORY—THE SPANISH INQUISITION, BY THE HON. JOHN COLLIER

Spain once led the world; she fell struck from within. Just as the Roman wars drained the physically worthy from Rome, and the blood from the future race of Romans, so ecclesiasticism in Spain set to work, in the Inquisition, to root out of the Spanish blood the qualities demanded for civilisation and progress.

Aulus Gellius, of the period—about A.D. 150—which Gibbon regards as the critical epoch of the decline, describes, in a long and remarkable passage, how the Roman mothers of his time were abandoning their natural duties, avoiding motherhood if possible, declining to nurse their babies when they became mothers, and calling in any wet-nurse, "without inquiry as to her suitability, though, as is often the case, she may be diseased or addicted to drink." Such references suffice to support the argument that a failure of the eugenic standard, as shown in the case of motherhood, undermined the living foundations of the Roman Empire.

Let us proceed now to the case of Spain. The modern argument invokes a racial poison to explain the decadence of Greece, war to explain the decadence of Rome, and now ecclesiasticism to explain the decadence of Spain. Spain was at one time a leader of the world. It produced great men of action and of thought, and was the heir and trustee of much science and art, which North Africa had preserved from the past, and from the East. But Spain fell. Rome had no more enemies to fear, and then she fell, struck at the heart, where empires rot.

How Spain was Struck Down by Her Enemies from Within

Spain also was stricken, not from without but from within—whence alone, as Wordsworth says, "proceeds a nation's health."

The double action of ecclesiasticism was directed on the lines of reversed selection. Just as the Roman military authorities removed the physically worthy and their blood from the Rome that was to follow, and thus selected not the worthy but the unworthy for parenthood, so ecclesiasticism set to work, as if it were of deliberate intent, to root out of the Spanish blood the two great sets of qualities which are demanded for civilisation, for national maintenance and progress. The Spanish Inquisition did its dire, anti-eugenic work in one direction; the ecclesiastical institution of celibacy—the negation of parenthood—as the highest human state, alone worthy of the highest human types, did no less disastrous work in the other direction. Between them they succeeded, to use Galton's strong phrase, in brutalising the breed of our forefathers. Here are the two celebrated paragraphs in which Galton made his indictment. These are quoted from his great work "Hereditary Genius."

Whenever a man or woman was possessed of a gentle nature that fitted him or her to deeds of charity, to meditation, to literature, or to art, the social condition of the time was such that they had no refuge elsewhere than in the bosom of the Church. But the Church chose to preach and exact celibacy, and the consequence was that these gentle natures had no continuance, and thus, by a policy so singularly unwise and suicidal that I am hardly able to speak of it without impatience, the Church brutalised the breed of our forefathers. She acted precisely as if she had aimed at selecting the rudest portion of the community to be, alone, parents of future generations.

The Terrible Policy of the Church which Brutalised Human Nature

The policy of the religious world in Europe was exerted in another direction, with hardly less cruel effect on the nature of future generations, by means of persecutions which brought thousands of the foremost thinkers and men of political aptitudes to the scaffold, or imprisoned them during a large part of their manhood, or drove them as emigrants into other lands. Hence, the Church, having first captured all the gentle natures, and condemned them to celibacy, made another sweep of her huge nets, this time fishing in stirring waters, to catch those who were the most fearless, truth-seeking, and intelligent in their modes of thought, and therefore the most suitable parents of a high civilisation, and put a strong check, if not a direct stop, to their progeny. Thus, as she brutalised human nature by her system of celibacy applied to the gentle, she demoralised it by her system of persecution of the intelligent, the sincere, and the free. It is enough to make the blood boil to think of the blind folly that has caused the foremost nations of struggling humanity to be the heirs of such hateful ancestry, and that has so bred our instincts as to keep them in an unnecessarily long-continued antagonism with the requirements of a steadily advancing civilisation.

The Vital Difference Between Ecclesiasticism and Religion

It would, of course, be inaccurate, and therefore unscientific, to speak of these disasters, greatly proclaimed by Galton's pen more than forty years ago, as caused by religion, notwithstanding that they were due to "the policy of the religious world." The proper word is "ecclesiasticism;" and we must be sure that we carefully recognise the vital distinction between ecclesiasticism and religion, or we shall come to grave error. It may be, indeed, declared that religion has always been eugenic, and that ecclesiasticism has always been the enemy of eugenics, as in these terrible instances.

If we turn now to France, which, great country though it still be, and a pioneer in many deeds of high emprise, is yet admittedly fallen from the glory of its past, both as regards physique and rate of national increase, and as regards influence in the councils of mankind, we find ecclesiasticism and militarism, twin enemies of man and of eugenics, both at work along the lines which Rome and Spain already illustrate. The France of to-day is the historical consequence of two tremendous racial disasters—the expulsion of the Huguenots and the Napoleonic wars.

The Two Terrible Disasters for which France is Paying a Bitter Price To-day

Such, at least, is the suggestion made, from the eugenic standpoint, in this attempt to survey and summarise the eugenic teaching of history. The expulsion of the Huguenots was precisely parallel to the murderous deeds of the Spanish Inquisition. Spain suffered and France suffered in just the same way. Just those priceless human qualities which Spain lost, France lost in her turn when the splendid strain of the Huguenots was extirpated from her blood and breed. One most notable difference remains, however. "Religious persecution"—to use a contradiction in terms—completely deprived not only Spain, but mankind, in most cases, of the qualities for future generations which led its victims to their martyrs' graves. But religious persecution in France, though it led to much murder also, chiefly led to expulsion of its victims to other lands. France lost as Spain did, but in this case other countries gained. Quite the chief gainer was our own country, the traditional home of liberty and asylum for the victims of persecution.

The Terrible Man of France who Sowed Ruin for its Future

We have only to examine the historical records of the Huguenot families that found a home here, so far as these records are available, in order to realise at once that the Huguenots whom we befriended were worth far more than their weight in gold to us. They have multiplied and intermarried with our own people, and have added, out of all proportion to their numbers, to the intellectual and moral quality and to the tangible achievement of our people. France's loss was England's gain. In the matter of *vital* "imports and exports" there can be no doubt as to the policy of "free imports"—*when those imports* are Huguenots or their like. Upon this irreparable loss there followed another. The manhood of France followed Napoleon Buonaparte in every direction throughout the Continent of Europe, and the greater part of it never returned. 'The soldier knew what he was doing. Like Frederick the Great, he sought to encourage physically fine fatherhood. In the Napoleonic code the mother of an illegitimate child has no remedy, for the search for the father is forbidden, the object of this being to avoid any legislative obstacle to the freest possible production of children.

According to Professor Richet, of the University of Paris, the Napoleonic campaigns must have cost in all not less than eight millions of lives. The drain upon the vigorous manhood of France was enormous, and, of course, involved a great fall in the birth-rate. The modern tyrant practised as vigorous a reversed selection as any of his predecessors. His battles had to be won, and he knew what kind of "food for powder" he wanted. He reduced by several inches, we believe, the physical stature of Frenchmen, and led them to unexampled victories abroad by depleting them of their only national wealth at home. The expulsion of the Huguenots was a disaster from the standpoint of moral and intellectual eugenics; the Napoleonic wars were a disaster from the standpoint of physical eugenics.

The Historic Tragedy of France, and the Tragedy on Russia's Horizon

The modern students of these subjects, whose studies have shown them how much heredity stands for in human affairs, may point to the present state of France as the consequence, and hope against hope for the future of a nation whose past is so glorious in science and literature and the noble arts of peace, but which is now at last actually declining in numbers, though its beautiful and fertile plains and valleys would support at least three times its present population. No one who remembers what England owes to the French Huguenots, and, with all the world, to the Frenchman Pasteur, can write scornfully of these historic tragedies, with their tremendous lessons for the ecclesiastics and the soldiers of all countries.

"Holy Russia," with its huge population, its high birth-rate, and its geographical relation to Asia, is one of the problems of the world. Only the ignorant suppose that, since Russia as a whole is backward, Russians are stupid or deficient. On the contrary, the highest types of Russians are the equals of any men and women

that can be found anywhere. In literature and painting and science, in the annals of liberty and martyrdom and intellectual and moral courage, Russia has a glorious record. If the Eugenist is asked how it can be that the nation which produces such great men is so backward, and is met with the argument that perhaps men matter less in national affairs, and institutions matter more, he replies that Russia practises, and has too long practised, reversed selection, as Rome and Spain and France have done. Russia produces noble morals and splendid intellect, but she exports them. Year by year she sends the flower of her manhood and womanhood to Siberia.

Many more, to escape a living death, exile themselves, often becoming notable and honoured in the countries of their adoption, including our own. The Jews of Russia and Poland are oppressed and murdered, their racial powers being destroyed, or compelled to turn, in self-defence, against the welfare of Russia. Under such conditions of reversed selection, when Russian and Jewish ability and moral courage are slaughtered and exiled, while stupidity and cowardice are left in peace, what chance of progress has a country, no matter how large its population, how full its nurseries, and how over-full its granaries, so that they largely feed the rest of the world?

The Practice of Robbing the Fatherland of its Best Fathers

If this argument be sound, Russia furnishes, indeed, a particularly instructive contribution to the supposed controversy between quantity and quality. Throughout the present chapter we have been meeting with evidence which suggests that quality is of the utmost importance, and that it must be reckoned with when we assert that there is no wealth but life. Starting from antiquity, up to our own times, we have seen evidence which suggests that not merely do birth-rates and population-pressure matter, but also it matters incalculably who furnish the birth-rate and who do not. No nation, it would appear, can indefinitely survive the systematic practice of reversed selection. This may be practised for military patriotism, as in Rome and France, but the patriotism—literally fatherlandism—which systematically robs the fatherland of its best fathers cannot but be fatal. In the instances before us the problem has depended not upon the factor of numbers, but upon that of parental quality. And now we see Russia, with every natural and numerical advantage, lagging behind the rest of Europe, and lamentably and doubly discrediting Europe by its war with an Asian people, and the result of that war, not because Russia produces no greatness, but because she destroys it and seeks to extirpate its stock; so that, indeed, generation after generation, Russia seems to fall further behind the level of advancing civilisation, and, having given mankind heroes and thinkers and martyrs in the past, now sends us, say—dancers.

The Tragic Problem of Ireland at Our Own Doors

Not that we who write and read in English characters can afford to point the finger of scorn at other nations. We have Ireland at our own doors. The present writer, being a Eugenist and accepting the invitations of any party indifferently if he can obtain a hearing for his creed, lately addressed a meeting of the United Irish League on race-culture, and sought the experience of his audience in answer to the question: Has Irish emigration involved reversed selection? The answer was affirmative. A distinguished member of the Irish Parliamentary Party told the meeting how he had lived for a quarter of a century at the great port whence young Irish of both sexes left Ireland for ever, and he agreed with many other observers in saying that these were the very flower of his country's youth—the vigorous, brave, enterprising, and devoted. If that is what Irish emigration has meant, the modern student of genetics and eugenics must declare, on every hand, that no country that ever was could survive such a drain upon its only wealth. Ireland will begin to be saved when the best of her young people remain in her, and only then. Whatever policy effects that end is right as national policy for Ireland.

Vital Imports and Exports from the Eugenic Point of View

Of course, it must be remembered that mankind as a whole does not lose in these cases. If good Irishmen leave Ireland for America, America gains what Ireland loses, just as in the case of the emigration of the Huguenots from France to England. All these arguments about immigration and emigration must therefore be looked at from the standpoint of the particular countries whose vital imports and exports these are—not from that of mankind at large.

This distinction prepares us to see clearly that exportation is no real remedy for the production of inferior human material. To send promising youth to Australia is good for Australia, but it is dangerous for us,

who are always ourselves in need of promising youth. To send hooligans and criminals, or probable criminals, to Australia may be very convenient for us, but it is very bad for Australia, which very rightly refuses to have any more of a process which did it harm enough a few generations ago. Good human material is not duplicated, bad human material is not disposed of, by exporting it. This obvious fact is forgotten by writers on these subjects, both at home and in the colonies. They very naturally see it only from the point of view of the man who fears to lose good material and wishes do what they can to produce good human material, and avoid the production of bad human material.

These, at any rate, are the questions to which the study of history and science leads us, and the national eugenics of the future will be built upon these foundations. We have to recognise "the astounding discovery, of which neither Adam Smith nor Cobden nor Malthus dreamed, that a nation is composed not of property nor of provinces, but of men." Let us continue to talk and argue and legislate about "imports and exports," but let us remember Rome and

Reproduced by permission of Eyre & Spottiswoode

MOTHERHOOD—BY JOHN LAVERY, A.R.A.

to lose bad, or of the man who wishes to get good and does not wish to get bad. But if we look at the matter from the human standpoint, or from the Imperial standpoint, it must be clear that good is good and bad is bad, wherever it is. The theory of the colonies as a "dumping-ground" for our undesirables was an insult to the colonies. No colonies would be worth having that did not resent it. On the other hand, the persistent drain of our best youth from the motherland must be disastrous. The true eugenic doctrine is that both motherland and colonies must France, and Russia and Ireland, and see to it that these imports and exports be living, and then indeed will the discussion be vital. If we would rebuild the living foundations of Empire we require a New Imperialism, a Eugenic Patriotism, which knows that nations are drawn out of nurseries, and accepts the scientific evidence, microscopic, historical, genetic, which verifies and ratifies for ordinary people the truth perceived in the past only by prophets and poets, such as the Irishman who said—

Ill fares the land, to hastening ills a prey,
Where wealth accumulates and men decay.

WOMAN—MOTHER OF THE WORLD TO BE

MADAME LE BRUN'S BEAUTIFUL PICTURE OF MOTHER AND CHILD, NOW IN THE LOUVRE

THE ULTIMATE UNIVERSE

The Mystery of the Two Worlds. What is Mind? No Matter. What is Matter? Never Mind

THE MATERIALIST IMAGE WITH FEET OF CLAY

The mind of the student, surveying the vast multiplicity of things, naturally seeks to reduce them to a list or category, so that it may be possible to form "clear and distinct ideas," in the famous phrase, and to formulate laws of Nature's working.

The tendency to classify lies deep in the mind; we all necessarily adopt this process in all our affairs. There is no other manner in which to get a grip of things, for otherwise their number and variety are too great for our minds to grasp. On the other hand, much of the business of science consists of breaking up and analysing, distinguishing between this and that, because they differ in some points, though perhaps alike in many more. These two contrary processes go on all the time; and the triumph of science is when they are found not to contradict but to help each other, so that, the more we distinguish and separate, the more we are able to simplify and unify, until the great scientific ideal of "unity in multiplicity" is realised.

Plainly the next task before us, in these chapters which are introductory to the study of the Universe, and therefore to the study of all the sciences, is to endeavour to reduce things to their ultimate categories, so that we may know all the kinds of existence of which the Universe is made, and may be able to refer every new object or identity to a place on our list. If we can do this we can do much more, for it means giving us definite ideas of the elements of our problem; and thereafter we should be able to discover the great modes of interaction between one kind of existence and another—those modes of interaction which we call the laws of Nature. We may notice that the same thing happens over and over again in the same circumstances, and call that a law of Nature, but even the lower animals have as much science as that. If our science is to be really worthy of the name, our laws of Nature must be general and universal; and if they are to be general and universal they must deal with the ultimate categories of things. That is why a list of things is an imperative necessity at this stage of our study.

If we consider and survey all the modes of being or existence of which we have any experience, one obvious and transcendent division of things first meets us, compared with which all other distinctions are simply trivial. On the one hand, there are things more or less visible and ponderable, which for many ages have been called Matter; and on the other hand there is a something, neither to be seen nor weighed, which knows and feels, and this we call Mind. As the witty proverb has it: "What is Mind? No matter. What is Matter? Never mind."

True, there is a final and peerless imbecility which denies the reality of mind, though that denial obviously invalidates itself, since it is mind that makes it. Here we shall not be so foolish. Our study in this section is wholly concerned with that which is not mind, but it is mind that writes and mind that reads; and we shall not so utterly stultify ourselves as to deny the primary condition of all our study, even though it is not to be called upon here to study itself. Our first division of the sum of all being is therefore into the ultimate categories of mind and matter; and from this point we must confine ourselves to the second of these until we have much improved upon the idea as the mere word "matter" states it. When we have done so, we must recognise what is, in some sense, the question of questions, namely, the

relation between mind and matter—a question which raises the most vital problems for and within every one of us at every moment.

Rather than speak of mind and matter, we should do better to speak of the psychical universe and the physical universe, believing, no doubt, that these two are ultimately one, but meanwhile accepting the vast distinction between them.

The Air We Breathe is as Much Matter as the Hardest Rocks

We must use some such term as "physical," because the word "matter" is entirely inadequate, and only refers to a mere fraction of the physical universe. Indeed, such is the present poverty of language that it would be more consistent if we could speak of mind and not-mind. Our business now is to reduce not-mind to its ultimate categories.

First on the list, as we may begin by supposing, is matter. Its claims are obvious, but we shall see that they may not be substantiated. Meanwhile, we grant them. Matter includes all material substance, irrespective of size or distance. Sirius and the sun are examples of aggregations of matter, and so is any one of the punctuation marks on this page. Questions of near and far, large and small, celestial or terrestrial, are irrelevant—matter is matter everywhere. Questions also of solid, liquid, gas, are irrelevant. Such matter as makes up water is equally and simply matter, whether it exists as ice, snow, hail, liquid water, or water-vapour. The air we breathe is as much matter as the hardest and heaviest rock; it may be liquefied or solidified, but is no more matter in these states than in its usual gaseous state.

The Materialist whose Doctrine has Received the Most Remarkable Condemnation

There is about matter, at least in the solid or liquid state, a satisfactory impression of reality, which our minds find it very hard to resist. We are not so sure about the gaseous form of matter, and we are apt to speak of "airy nothings," but the casual mind tends to regard matter in general as the most real of realities. Hence there is derived a definite theory of the Universe, which is appropriately called Materialism.

This hopeless and uninspiring notion of things had its heyday some half-century ago, at the dawn of the modern scientific era. It has received in recent years the most remarkable condemnation. Further study—of the very kind upon which the materialistic theory was orginally based—has disposed of it for ever, by disposing of matter as an ultimate reality at all. This most unpleasing image of the human mind's invention had feet of clay, and they have already crumbled into dust. We can no longer include matter anywhere in our list of ultimate things; and the theory which built mind and all other existence thereon is left "to point a moral and adorn a tale."

As we have already seen, the modern analysis of matter resolves it into electricity, and electricity is itself found to be a form of energy. Like all forms of energy, it is convertible into any other form of energy, and any other form of energy is convertible into electricity. The old division of the physical universe into "matter and energy," which provided material for so much writing and so much angry controversy only a generation ago, breaks down. Matter becomes resolved into a mode or manifestation of energy. If we are to have a philosophy which elevates the physical above the psychical, we can no longer call it materialism, but, if anything, must call it energism.

"Ether is the Mother of Matter and Energy is its Father"

Our list of things thus becomes smaller and more profound! All forms of matter, "from stars to street-sweepings," all compounds and all elements, take their place as manifestations of energy, and all manifestations and modes of energy are found to be convertible, and therefore ultimately one. Matter, motion, light, heat, sound, electricity, magnetism, chemical energy, all these come under one name in our list: they are all of them "energy." We are inclined to ask whether anything remains.

The answer is that we have not yet reckoned with a mysterious something, invisible, yet the vehicle of all light, which is not matter, and is not energy, and is called the ether. It comes to this: that for the older pairs of terms, "matter and energy" or "matter and motion," we must substitute "ether and energy." Our list of things, so far as the entire physical universe is concerned, may be reduced to these two, and to them alone.

As the French scientist Gustave Le Bon has put it, "Ether is the mother of matter," and perhaps we may now go a step further, and say that ether is the mother of matter and energy is its father. Le Bon has given us a most suggestive analogy when he compares the genesis and dissolution of what we call matter to the formation and melting of

icebergs in the ocean. That ocean, universal and continuous, is the ether.

Here is an idea which has grown from small beginnings, and has survived much ridicule, until it has attained pre-eminence in modern thought. Just as electricity was at first no more than a singular property of amber—of which the Greek name is electron—and has now become recognised as the form of energy of which all matter is constituted, so the ether, originally "invented" as a necessity of rational speculation for particular purposes, has become recognised as the universal medium, the womb and tomb of all things.

The Mysterious Something that was Supposed to Carry Light

We first hear of what used to be called the "luminiferous"—that is, the light-bearing—ether. Sound travels through matter—air, water, or rock. Where there is no matter, there is no sound; no earthly sound can reach the heavens. But light travels from star to star, or sun to planet, where there is no matter at all. Men have believed, as Newton did, that light consists of a multitude of minute bodies, called by him corpuscles, which are shot through space from the luminous object. But when this "corpuscular theory" of Newton's was found to be unsatisfactory, there followed the "undulatory theory," which declared that light consists of undulations, or waves. Plainly we must inquire—waves in what? For these waves are evidently conveyed where there is nothing that we know. We are bound to assume the existence of a medium, and that, from its function, was called the "luminiferous ether." About it no more was asserted than that it was *not* matter, but was certainly real, and that it was capable of conveying waves, so that it must have the property, familiar in many forms of matter, which is called elasticity.

The Unseen Ether that is More Real than the Things We See

But Newton's name is associated with another theory which has stood the test of time much better than his corpuscular theory of light. He declared that the motions of the planets can only be explained on the view that there is an attractive force exercised between them and the sun. Now, if the force or action be exercised, we are bound to believe that there exists some medium through which it is exercised. The alternative is to believe in "action at a distance," the exceedingly stupid name for action exercised by one thing upon another without any sort of intervening medium.

Now, "action at a distance" simply cannot be imagined, and gravitation is a fact; therefore there must be a medium, filling space, which we may call the ether. And we may not unreasonably suppose that the ether or medium which conveys light also conveys the force of gravitation; nor will this view be any the less satisfactory if the physicists discover, as they may, that the force of gravitation is electrical in nature, as we know light to be. At the present day we are acquainted with a large number of other forces and radiations, such as magnetism and radiant heat, which also demand the existence of a medium for their transmission, and that medium is undoubtedly the ether. The positive, scientific, objective reality of this ether needs to be insisted upon, as many critics who are not acquainted with recent scientific developments still incline to the view that the ether is a kind of legend, not to be taken seriously. To modern students of these subjects the ether is far more real than obvious matter, though the type of mind will perhaps always persist which denies the reality of whatever is impalpable.

The Great Chemist who Thought Ether to be a Material Thing

Absolute certainty that the ether exists is not incompatible with the utmost doubt regarding its properties. The doubt, and the differing opinions of students, evoke the jeers of critics who are themselves so far removed from giving any help that they are totally incapable of appreciating even the difficulties which are involved in the problem. No one can pretend that these difficulties are yet solved, but they are in process of solution. Some recent points of view may here be briefly considered.

The great Russian chemist Mendeleéff, recently dead, propounded in the last years of his life the view that the ether is really none other than a form of matter, that it is, indeed, one of the chemical elements; and he endeavoured to find a place for it in the table of the elements which it is his lasting honour to have given to the world. The opinion of Mendeleéff is not accepted, but it is worth recording, not only for its historical interest, but particularly because it shows how a great student of the forms of matter was so convinced of the substantiality of the ether that he could place it on a par with ordinary matter.

If we consider the motions of the heavenly bodies, we begin to realise the difficulty of the problem before us. We know for certain, since it cannot be otherwise, that space is filled with a something, which we

have agreed to call the ether, though the name matters nothing. As the earth travels through space many miles in every second of time, what does it do to the ether, and what does the ether do to it? Does the ether part in front of it, as the air and water part in front of a ship? We find it hard to suppose anything else, yet the difficulties involved in this view are so great as to be probably insuperable.

Does the Earth Divide the Ether as it Passes Through It?

So great are the difficulties of believing that, say, the earth can divide the ether as it passes through it, that students have sometimes preferred to consider the possibility that, as earth or sun or any star or comet moves through space, the ether of space travels through the material body, as water might move through a porous body such as a sponge.

Other astronomers, looking at the relations of earth and ether as comparable with those of ship and sea, have questioned whether, and, if so, to what extent, the ether retards the heavenly bodies, by its having to be parted in front of them, and by its friction upon them as they pass. If such friction occurs, no matter how inconceivably minute its extent, then in the vast measures of astronomical time it must produce enormous consequences. Granted the existence of such friction, it is only a matter of time for the speed of such a body as the earth to be so much retarded that it can no longer maintain an orbit, and must fall headlong into the sun. This is one of the many problems, still awaiting elucidation, involved in the existence of the ether.

If we endeavour to compare the ether with ordinary matter—we find we have to use the word "ordinary," for it is impossible to think of the ether except as a kind of matter—we naturally incline to the view that it must be inconceivably light and rare and tenuous, compared even with the lightest form of matter that we know, which is hydrogen gas.

The Idea that the Earth is an "Empty" Part of the Universal Ether

Yet the mathematical astronomers are more and more inclining to accept a view entirely opposed to this, and are crediting the ether with a density and potency which transcend all ordinary matter, however concentrated; and we have indeed been latterly asked to conceive of material things, such as our earth, or any lesser or greater portion of matter, as places of comparative emptiness and vacuity in the universal ether—a notion which directly contradicts all that we naturally suppose, and which yet has much to be said for it.

If we are asked as to the structure of the ether, we can only reply that we suppose it must be structureless. It must be continuous and non-atomic, just as definitely as matter, or "ordinary matter," is discontinuous and atomic. Something happens in it wherever what we call matter is to be found; and it suffers stresses of some kind whenever it transmits any form of what we call ether-waves, though it must be questioned whether the term "waves" is much more than a figurative expression to help our minds.

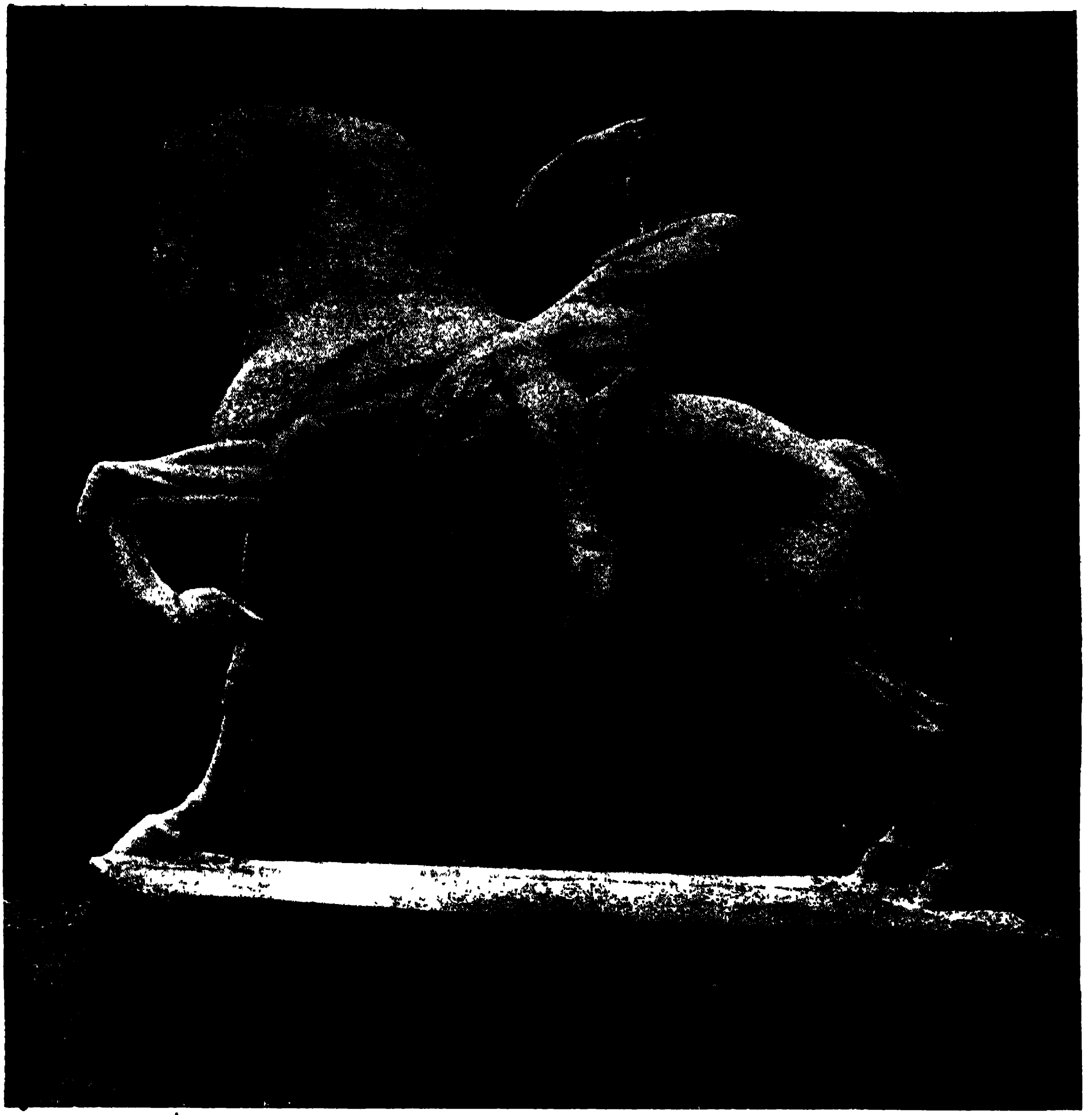
Having satisfied ourselves that the ether exists, and that it is one of the two ultimates of the physical universe, we must ask what is its relation to the other entity, which we call energy. Here we are in deep water, but certainly the more obvious view is the wrong one. We incline to think of the ether as something, itself passive, which is acted upon by matter, or acted through by matter, as when gravitation attracts, or when radiations of heat or light are poured forth from hot or glowing bodies.

The Transformations and Interactions upon which Evolution Depends

This conception of the ether is radically and fundamentally wrong. As Sir Oliver Lodge and many others have pointed out, the ether is crammed with energy, very nearly measureless in quantity. We cannot, as yet, tap that energy, any more than we can tap the energy inside the atom; perhaps the key to the one may be the key to the other. But there it is; and any mental picture of the ether which omits to include it is inadequate and useless.

Let it be fully granted that the problem of constructing a mental picture of the ether which will satisfy all the demands made upon it by science is at present insoluble. It will yet be solved, and meanwhile we have enough to justify us in the assertion that the most ultimate and simple category of the physical universe which we can frame reduces the list of things of which it consists to two—ether and energy.

What we have called universal evolution therefore depends upon and consists of the transformations and the mutual interaction of ether and energy. This statement practically agrees with Herbert Spencer's conception of physical evolution, except that we substitute "ether and energy" for "matter and energy." These transformations and interactions proceed in an orderly way;



A GREAT ARTIST'S CONCEPTION OF PHYSICAL ENERGY—THE STATUE MADE BY MR. G. F. WATTS FOR THE TOMB OF CECIL RHODES

"Ether is the mother of matter," said Dr. Gustave Le Bon, and we may now go farther and say, "Ether is the mother of matter and energy is its father." This photograph of the statue is the copyright of Mr. Frederick Hollyer.

and when we observe the order in given cases, or sets of cases, we speak of the "laws of Nature." We might just as well speak of the "laws of ether and energy." But there are few scientific terms so constantly abused; and since we cannot escape its frequent employment, we had better look at it closely.

We can scarcely speak of a "law of Nature" without thinking of human laws and lawgivers; nor can we well forget that laws are alterable, lawgivers change their minds, laws come into force on certain dates and cease on other dates. In all such respects as these there is ***no resemblance whatever*** between human laws and lawgiving, and what we call the laws of Nature. That is the first point which we must clearly and lastingly keep in mind, and it is quite sufficient to show that the term is a bad one. Scarcely less important is the fact that we apply this term, unwisely and indiscriminately, to all manner of so-called laws, which are totally unlike each other.

Twice two, for instance, is four. This is not a law of Nature. It has nothing whatever to do with Nature's events, nor their mode of occurrence. Whatever the interactions and evolutionary transformations of ether and energy may be, such a law as this of arithmetic throws no light upon them, expresses no part of them, and is wholly independent

of them. Such laws as these are not "laws of Nature" in the usual and useful sense of that term. They are laws of thought. What we call the laws of Nature may be true or false. They may apply, at best, only to our little portion of time, only to our little portion of space. But the laws of thought, the fundamental doctrines of logic and of mathematics, remain. The external world does not matter to them, they are wholly independent of it. Chaos might supervene, the laws of gravitation and motion and life might all disappear, and the propositions of logic and arithmetic would be just as true. They are true because they correspond with and answer to themselves and each other. Four involves and contains the idea of twice two, and that is enough. The truth of the other so-called "laws of Nature" and our theories of her working depends not upon the logical and reasonable character of our theory—though that is necessary if we are to believe it—but also upon *the correspondence between the theory and the facts.*

The False Theories which Strew the Path of the Scientist

The records of science are strewn with false theories which were beautifully consistent with themselves and read most convincingly, but failed to correspond to the facts. Since we are rational beings, we all love a beautiful theory, but we have to beware lest the beauty of our theories blinds us to the facts, by which, in the last resort, the theories will be judged. Nothing could be more beautiful, consistent, appealing, than Professor Lowell's theory of Mars, but no one knows better than its author that this theory must be judged by the facts, not by its internal consistency. Nothing could be more magnificently satisfying to the mind than Newton's law of gravitation, but Newton waited many years before publishing it, because the inaccurately recorded facts before him did not tally with the law. Lesser men would have made the facts square with the theory. Newton kept the theory in abeyance until he was satisfied that it squared with the facts.

Mathematics—including geometry—long called the "queen of the sciences," does not enter into our present scheme. Here we recognise the existence of this noble science, and acknowledge that, of all the descriptive sciences, astronomy owes most to mathematics, and will owe more in the future. But having done so, we must insist that it is not for mathematicians to impose their conclusions upon the existing world. Mathematics is the only accurate science, its laws are the only certain laws, because they are all necessary, and could not be otherwise. Mathematicians start out with certain assumptions about Nature, and argue therefrom in their inimitable fashion, and then come to such and such conclusions.

"The Cradle-Songs with which the Teacher Lulls his Pupils to Sleep"

The observers of Nature are constantly discovering that these conclusions are wrong, because the original assumptions were imperfect. "Hypotheses," said Goethe, "are the cradle-songs with which the teacher lulls his pupils to sleep." Again and again this has happened. Mathematicians have made this or that assertion about flying-machines, or the nurture of school children, or the distribution of the stars, or what not, and have sought to silence all discussion, because they were justly certain of the validity of their logical processes, and then they have turned out to be wrong.

Those "laws of Nature" to which alone the term should be restricted cannot hope to boast the certainty and the accuracy and the superb independence of the laws of thought, of logic, of numbers, and the like. The students of Nature—that is, of the physical Universe—can only observe to the best of their ability, put their observations together, and state general modes of action, which may just as well be called the habits of Nature as the laws of Nature. But our observation may be wrong, and, if so, we must hasten to correct it. The critics of science will jeer, but the wise will know that science is therein the more honoured. And even though our observation be correct, the laws of Nature may not remain, because Nature may change her habits.

The Lesson of Evolution—that Nature is not a Being, but a Becoming

Universal evolution teaches us that Nature is not a *being*, but a *becoming*. Change is her most deeply rooted habit. In other words, the evolving universe behaves thus, at one time, and thus, at another time; thus, in one place, and thus, in another. We may boast ourselves to be "surveyors of all time and all existence," but there is no warrant for the boast. We should not admit the pretensions of an ant to such a survey. How can we admit our own?

The lesson and the meaning of all this is that we must be humble. We shall study the law of gravitation, the laws of planetary motion, the laws of motion in general. Elsewhere we study the laws of life and death, the laws of health, and so forth. What men

of science believe they must boldly promulgate and stand by, so long as they believe it, but none of these laws and statements are final. When men in the last century first completely grasped the mighty idea of the order of Nature, they were far too confident in asserting this and that to be part of her everlasting laws, and far too ready to be content with accepting them, instead of humbly going on to question and to observe. Science has been too often discredited in consequence, and hampered in its progress.

The Horrible Nightmare that Materialism Sought to Impose upon Us

The nineteenth, the "wonderful," century already begins to be seen as not only a century of superb discovery, but also a century of many confident mistakes. Our almost immediate predecessors boldly announced laws about the nature of atoms, laws about the eternity of matter, laws about the dissipation of energy, laws about the origin of species, and so forth, which we now know to be either doubtful or only half-true, or else wholly untrue.

Materialism was one of the horrible nightmares which men sought to impose upon mankind in consequence. The history of that degradation should give us pause. Here let it be set forth in words the clearest and most conspicuous that this kind of insolent dogmatism, never surpassed by ecclesiasticism at its worst, is not for us. On the contrary, we here recognise that the sum of things may be divided into two parts, one of which is mind, and the other is not-mind—the psychical aspect and the physical aspect of the universe respectively. The physical aspect of things we have summed up in a brief list of two items only, ether and energy. What we call the "laws of Nature" are there concerned. What we call astronomy, old or new, is concerned with large-scale doings, changes, and interactions of ether and energy. We call this section "the Universe," and the students of the objective sciences are content to assume that what they deal with, if they could only probe it deep enough, is the universe and the whole universe.

Is the Psychical Nearer the Real than the Physical, and is Light the Shadow of God?

But be it here most solemnly stated that we acknowledge the existence of the other aspect of things, which we call psychical. Though we boast that we deal with the Universe, it is only one of its two aspects that we shall consider. The world of mind and thought and feeling, with its laws, its breadth, and depth—that is outside our present purview. Physical science has never yet answered the arguments which assert that the psychical is the nearer aspect of reality; that the external world, commonly called "the Universe," is only appearance or phenomenon; that light is only the shadow of God. The world of mind has its pioneers, however, in our own day. They pursue what is called psychical research, immensely scorned by orthodox men of science, just as orthodox doctors scorned Harvey, and astronomers Copernicus, and theologians Buddha and Socrates and a Greater still. Psychical research is as yet in its infancy, and its followers are few. But it is joining hands with its elder sisters, philosophy and psychology, and has allies—and no wonder—among the mathematicians, who live in the world of thought, and know that it is real and has its own irrefragable laws, which no cataclysm nor any evolution of the external Universe can alter.

In this section, therefore, we deal with only the physical aspect of the Universe; and in closing these introductory chapters only one question remains: What is the relation, what the interaction, between physical and psychical, between mind and not-mind? Are they ultimately two, or ultimately one? In either case, how, if at all, do they affect one another?

The Mind Behind our Mind, and the Unknown Beyond the Known

The doctrine that mind and not-mind are ultimately two is known technically as dualism; the doctrine that they are ultimately one is known as monism. In our use of terms, speaking of the physical and the psychical *aspects* of the Universe, we have committed ourselves to monism as against dualism. We would argue that mind and not-mind, subject and object, psychical and physical, are the inside and the outside of one reality, and that behind what we call not-mind there is also Mind akin to ours, Mind Universal and Divine, of which our minds are sparks.

Lastly, the student of the Universe is posed with the question whether mind and not-mind, as in ourselves, move in parallel, without affecting each other, or whether they interact. The former doctrine, now very popular, is known as "psycho-physical parallelism." The alternative doctrine of interaction is no less well attested. The issue does not concern us, so long as we distinguish between the laws of thought and the laws of Nature, and realise that the psychical aspect of the Universe is no less real and no less important than that which we here study.

THE PERILS MEN WILL FACE FOR GOLD

Gold has been the motive power of most of the tragedies and many of the comedies of the world. Men have crossed mountains, and spilt blood, and crushed rocks in search of it. The goldfields are pre-eminently the poor man's opportunity to either make a fortune by steady work with pick and spade, or to achieve fortune at a bound by a lucky find of a nugget worth thousands of pounds. In this picture a group of gold-seekers are descending the Chilkoot Pass on the way to the Klondike.

INSIDE THE EARTH'S CRUST

The Metals with which "Man has Hacked and Blazed His Way Through the Dark Jungles of Barbarism"

A SURVEY OF THE LEADING METALS

We have mentioned the substances that play the chief part in the constitution of the crust of the earth; but the earth's crust is "full of a number of things" that play other parts than mere crust-making, and are of particular interest to the living beings inhabiting the crust. Chief among those interesting things are the metals. So important are metals to civilised man that some are used as milestones and landmarks of progress, and it is common to talk of the Stone Age, the Bronze Age, and the Iron Age. With metals, indeed, has man hacked and blazed his way through the dark jungles of barbarism.

What is a metal? The term is too ancient to be scientific, and, though science uses it, science has not succeeded in giving it a very sharp and distinct definition. But certain substances are put in one class and called metals, because they have certain characteristics more or less in common. They are lustrous; they are good conductors of heat and electricity; they are usually rigid when cold, yet show a certain amount of elasticity. Most are opaque to light; but gold, if beaten out into very thin leaves, transmits green light, and thin films of mercury transmit light of a violet-blue colour. Probably all are capable of assuming a crystalline structure, and some, such as zinc, show crystals quite clearly. But perhaps the features that induce and justify the classification of metals are the properties of plasticity, malleability, and ductility, which have rendered certain substances so useful.

The plasticity of metals, their capacity for being moulded as a potter moulds a bowl, varies in individual metals and depends on circumstances. Thus, potassium and sodium, even when cold, can be worked with the fingers like wax, and lead and thallium are also easily moulded at ordinary temperatures. Others, such as zinc, iron, and lead, become readily plastic only when heated. Even those hard metals which seem to lack plasticity are, however, really quite plastic, as has been shown in quite a sensational way by H. E. Tresca, who made a cylindrical cavity in a block of steel and made a hole in the bottom of the cavity that reached to the exterior of the block. He then put little discs of metal into the cavity, and by means of a piston working under hydraulic pressure he subjected the discs to a pressure of over 200,000 pounds. Under this pressure even such a hard metal as iron was squeezed like putty through the hole in the bottom of the cylinder.

In some metals the malleability, or the capacity for being flattened into thin sheets by hammering or pressure, and ductility, or the capacity for being drawn out into wire without breaking, are most remarkable. Gold-leaf, for instance, can be beaten out till it is only a 95,000th part of an inch thick. A single grain of gold has been pounded out so as to have a surface of fifty-seven square inches, and platinum can be drawn out into a wire so fine that half a million could come into a single inch.

Metals vary in colour: many are white or grey; but gold is yellow, and copper is reddish. Metals also vary in weight. Potassium, lithium, and sodium are light enough to float on water. Silver, on the other hand, is more than ten times the weight of water, and platinum and osmium are more than twice the weight of silver. All metals may be melted, but each metal has its own melting-point. Mercury melts at $-39°$ Fahr. Potassium and sodium melt below the temperature of boiling water. Silver and gold melt at a temperature of 962° and 1064° centigrade respectively. Platinum requires a temperature of 1760°

centigrade to melt it, and osmium can be melted only in the terrific heat of the electric furnace.

The principal metals are aluminium, iron, sodium, potassium, calcium, zinc, tin, copper, lead, silver, gold, platinum, manganese, mercury. Many metals are very rare and difficult to obtain; ruthenium, for instance, is so rare that it costs over £20 an ounce.

It must not be thought that all the metals occur in a pure state in the crust of the earth. A few, such as gold and platinum, are found practically pure, but most of them are oxidised and mixed with foreign material, forming ore from which they require to be extracted by various processes. We need not here discuss the metals individually, but the more interesting and important may be considered. And first must come iron.

The Iron Age began in different countries at different times. In Egypt, Chaldæa, Assyria, China, iron was used nearly 6000 years ago. In Etruria iron was known about 1400 years before Christ, and in Gaul about 600 years later. According to the poems of Homer the ancient Greeks used iron about 1200 years B.C. In England the Iron Age began later still, but iron was worked by the ancient Britons before the invasion of Julius Cæsar. In Russia the Iron Age began only 1100 years ago.

The term Iron Age has a really deep significance; iron is the material foundation of the world's mechanical energies—its Atlantic liners, its Dreadnoughts, its aeroplanes, its motor-cars, and all its multifarious machinery. The great iron-masters are and must be the great world-masters; iron, cleared of dross and mixed with brains, is the great lever of the world.

Without iron, civilisation would be hardly possible. It owes its paramount importance to its unique versatility and adaptability—a versatility and adaptability rivalled by no other substance. Razors, nails, battleships, watch-springs, horseshoes, bridges, darning-needles, files, handcuffs, pokers, skyscrapers, and a thousand other manufactured articles, testify to its divers uses. And the spear may readily be made a pruning-hook, and the sword may readily be beaten into a ploughshare. It can be made hard or soft, strong or weak, brittle or plastic, fusible or infusible. The blacksmith in some countries tests the iron nails for his horseshoes by bending them on his forehead, and yet iron projectiles can be made hard enough to pierce the thick armour of battleships, or to smash hard ore, as one might break a lump of sugar with a pestle.

Strangely enough, the qualities of iron depend largely on the amount of foreign matter it contains and chiefly on the amount of carbon it holds, and all the resources of metallurgy have been devoted to producing the iron and carbon in right proportions.

IRON AS IT IS BROUGHT OUT OF THE EARTH

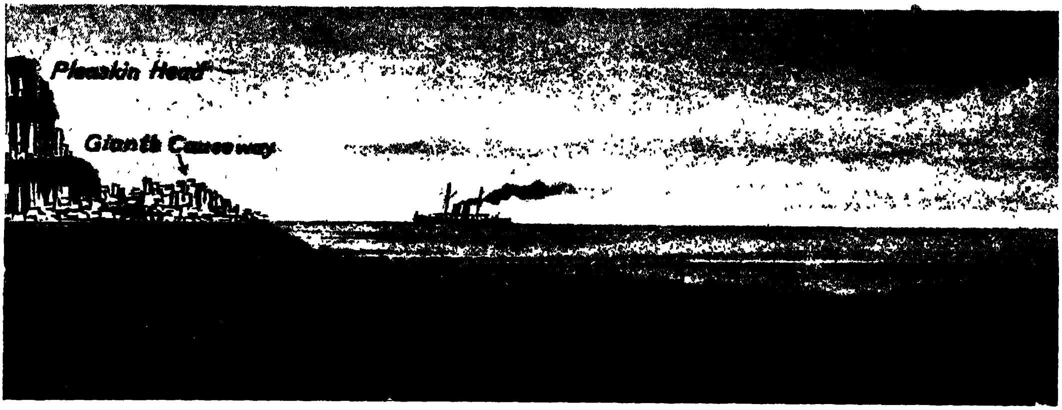
Iron is, of course, indispensable as the medium of mechanical activity, but it performs other functions in the world that must not be forgotten. Owing to its ductility and plasticity iron forms a most serviceable medium for art. Well does Ruskin put it in language which, though perhaps more eloquent than scientific, we may well be pardoned for quoting here:

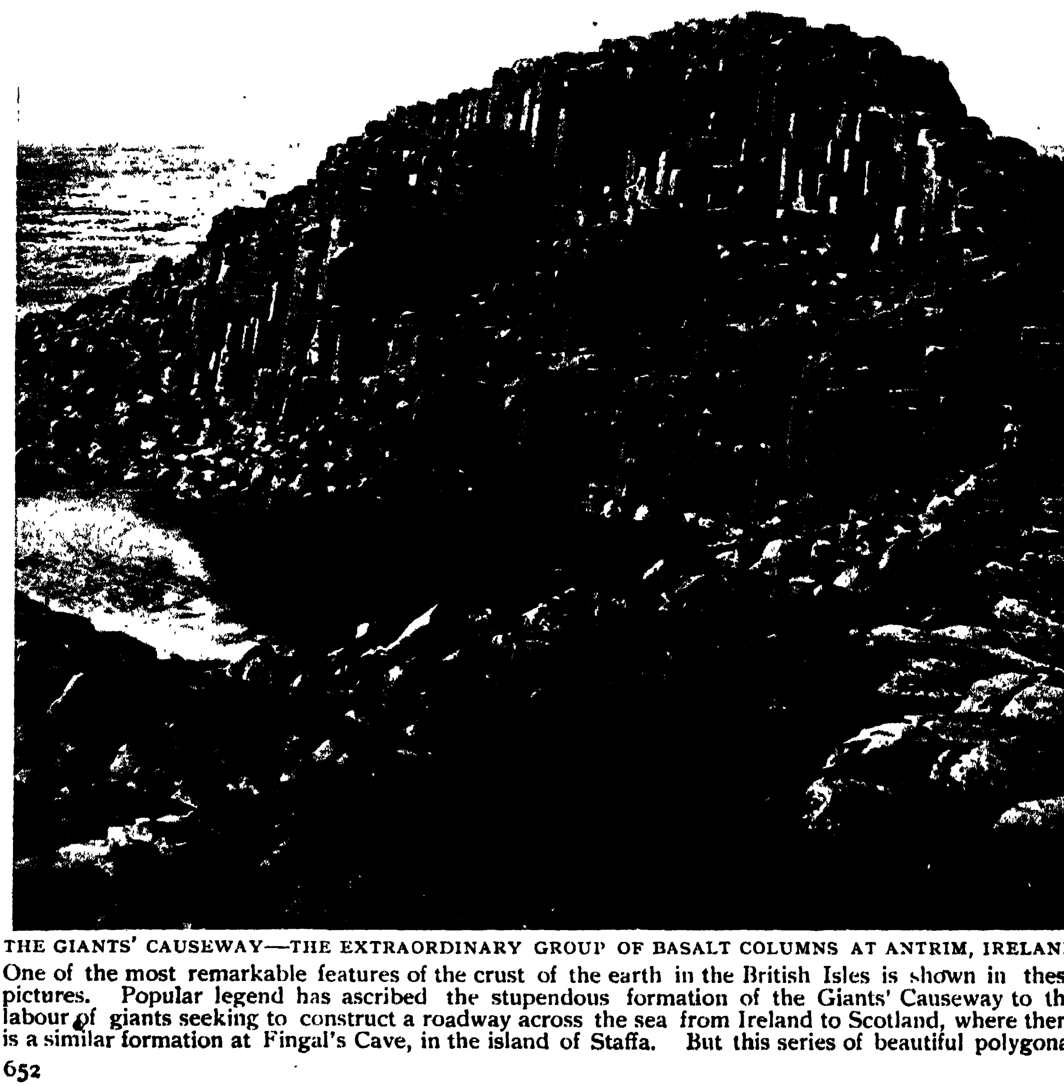
> When you want tenacity, therefore, and involved form, take iron. It is eminently made for that. It is the material given to the sculptor as the companion of marble, with a message, as plain as it can well be spoken, from the lips of the earth-mother. Here's for you to cut and here's for you to hammer. Shape this, and twist that. What is solid, simply carve out; what is thin and entangled, beat out. I give you all kinds of forms to be delighted in: fluttering leaves as well as fair bodies; twisted branches as well as open brows. The leaf and the branch you may beat and drag into their imagery, the body and brow you shall reverently touch into their imagery. And if you choose rightly and work rightly, what you do shall be safe afterwards. Your slender leaves shall not break off in my tenacious iron, though they may be rusted a little with an iron autumn.

Nor do the services of iron to art cease here. Iron gives much of its colour to the world, making the blood red, and the leaves green, and the soil umber. Iron is the basis of many colours, and without

HOW IRON SERVES THE NEEDS OF MEN

THE IMMENSE VARIETY OF NECESSARY THINGS FOR WHICH WE DEPEND UPON IRON AND STEEL

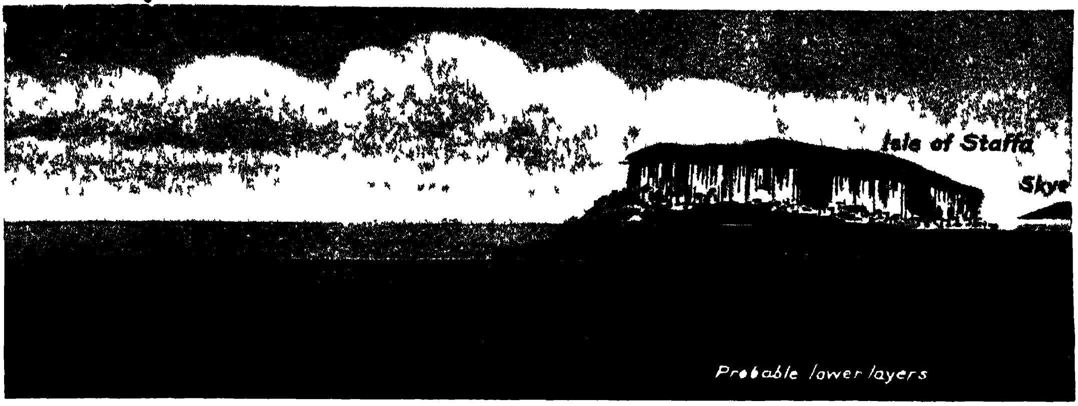




THE GIANTS' CAUSEWAY—THE EXTRAORDINARY GROUP OF BASALT COLUMNS AT ANTRIM, IRELAND

One of the most remarkable features of the crust of the earth in the British Isles is shown in these pictures. Popular legend has ascribed the stupendous formation of the Giants' Causeway to the labour of giants seeking to construct a roadway across the sea from Ireland to Scotland, where there is a similar formation at Fingal's Cave, in the island of Staffa. But this series of beautiful polygonal

THAT LEADS FROM IRELAND TO SCOTLAND



THE BEAUTIFUI CAVE IN THE ISLAND OF STAFFA, SCOTLAND, TO WHICH THE GIANTS' CAUSEWAY LEADS

columns owes its formation to the same great forces to which are due the transmutation of wood to coal, the crystallisation of carbon in the form of diamonds, and the melting of rocks and their throwing up from the depths as lava or volcanic islands The causeway is believed to have hundreds of thousands of columns of the oldest known rock, and to extend from Ireland to Scotland

it the world would be anæmic, a dirty white—" the white of thaw, with all the chill of snow in it, but none of its brightness." As Ruskin points out, it is the rusting of the iron, its oxidation, that renders it so useful for such purposes.

"We suppose it," he says, "to be a great defect in iron that it is subject to rust. But not at all. It is not a fault in the iron, but a virtue, to be so fond of getting rusted, for in that condition it fulfils its most important functions in the universe and most kindly duties to mankind. Nay, in a certain sense, and almost a literal one, we may say that iron rusted is living; but when pure or polished, dead."

"The Colour that Comes from the Breathing of Iron"

The iron-rust is just iron plus air. The iron breathes air just as we do, "and as it breathes, softening from its merciless hardness, it falls into fruitful and beneficent dust, gathering itself again into the earths from which we feed and the stones with which we build, into the rocks that frame the mountains and the sands that bound the sea." Agates, jaspers, cornelians, bloodstones, onyxes, cairngorms, chrysoprases, marble, porphyry, red granite, blue hills, russet fields, red tiles, green moss, rosy granites, and rosy cheeks all owe their colour largely to this wonderful rust of iron. "Is it not strange to find this stern and strong metal mingled so delicately in our human life that we cannot even blush without its help?"

So much for iron. Let us look now at the very common metal aluminium, which we have already mentioned as forming eight per cent. of the crust of the earth. Aluminium is as common as clay: the bricks and slates of our houses, the china of our dishes, are full of aluminium. But it required great skill to obtain it in a pure state, and only within the last few decades has it been possible to produce it cheaply. Fifty years ago it cost about twenty shillings an ounce; now we can buy more than twenty pounds for that price.

The Properties that Give Aluminium its Great Industrial Value

It is a soft, white metal like tin, and melts at 655° centigrade. It is the third most malleable and most ductile of the metals; it cannot be beaten out so fine as gold nor drawn out so fine as platinum, but it can be beaten out into sheets of a 4000th part of an inch thick, and drawn out into wire one 250th part of an inch in diameter. It is also a good conductor of heat and electricity—such a good conductor of electricity that it often is employed for that purpose instead of copper. Its tensile strength is also great; weight for weight it is beaten in this respect only by the best cast steel.

In all these respects aluminium excels; but it owes its value to three other properties: it is not easily oxidised, it is not easily corroded by acids, and it is very light. Since it is not easily oxidised, it does not rust away like iron in the presence of moisture and air: and since it is not easily corroded by acids, and is very light, it is obviously fitted for eating and cooking utensils, and is now largely used in the manufacture of such utensils. The uses of aluminium in our day are very numerous, and aluminium is largely replacing brass and copper in many branches of industry. We will only mention here that aluminium is now used in boat-building, in torpedo-boats, in fittings for ships instead of wood, and for making engines, motor-cars, bicycles, tools, scientific instruments, aeroplane fittings, and that the range of its usefulness is steadily increasing.

The Unique Characteristic of Metals which Help Forward Human Knowledge

Powdered aluminium burns vigorously, like magnesium, and a mixture of powdered aluminium and iron oxide, known as thermit, burns so fiercely that if a little be ignited on an iron plate half an inch thick it will burn a hole right through. Thermit is used in various welding operations.

Like iron, aluminium plays a part in the æsthetic side of life. If iron colours gems, it is aluminium that forms their basis. Corundums, sapphires, topazes, amethysts, rubies, and many other precious stones are chiefly glorified aluminium-clay.

Another interesting metal with characters of its own is platinum. Platinum is a soft, white, lustrous metal found chiefly in Russia. It is found almost pure, so no elaborate metallurgical operations are required to obtain it. Nevertheless, unlike aluminium, its price has almost quadrupled in the last twenty-five years. It is very malleable and ductile. Its melting-point is 1760° centigrade. Like many other things, it owes its importance to certain almost unique properties it possesses. It is practically unoxidisable, and it resists all acids except a mixture of nitric and hydrochloric acid, which slowly dissolves it. These properties make it *the* metal for chemical utensils and crucibles. It is used also for making stills for the concentration

of sulphuric acid. Liebig, the great German chemist, said that "without platinum crucibles, which share the infusibility of porcelain with the chemical inertness of gold ones, the composition of most of the minerals could not have been ascertained."

THE SUCCESSOR OF THE ALCHEMIST—FATHOMING THE SECRETS OF MATTER IN A LABORATORY

The alchemist of the Middle Ages searched for the Philosopher's Stone that would transmute all base metals into gold; the alchemist of our own day searches for the properties of matter which will reveal to us the ultimate foundations of the universe.

Platinum owes its value also to a lucky chance—to the chance that it expands and contracts to heat and cold at the same rate as glass. It can therefore be used to penetrate the glass globe of electric lamps and carry the incandescent filament. As the glass expands and contracts, so does the platinum, and thus the bulb remains airtight.

Finally, we come to gold. Gold is found in many countries, and, being easily obtained and easily worked, it was one of the first metals to be used by man. The ancient Babylonians, Assyrians, Egyptians, Cretans, were all well acquainted with this precious metal, and it is very probable that in many countries gold was used for money long before silver or copper.

The beauty, the lustre, the indestructibility of gold have at all times made it the symbol of desirability—"more to be desired is she than gold, yea, than much fine gold"—and the standard of value. Men have crossed mountains, and spilt blood, and crushed rocks in search of it.

The Gold that has Drawn Armed Men from Civilised Lands into the Wild

It has been the great motive power of military conquest. This hunger it was "that led Scipio to Spain and Cæsar to Gaul, that impelled Columbus to Cathay, Cortes to Mexico, and Pizarro to Peru. It led Clive to the conquest and Hastings to the plunder of Bengal." And it has been a motive power, too, in chemical research, for nothing stimulated the chemical industry of the alchemists of the Middle Ages so much as the hope of discovering the Philosopher's Stone that would transmute all the baser metals to gold. Though they did not find the Philosopher's Stone, they found many other things.

Like platinum, gold is invulnerable to acids, and is attacked only by a mixture of hydrochloric and nitric acids. It is naturally a soft metal, softer than silver, and almost as soft as lead, but if alloyed with a minute quantity of lead, cadmium, or silver, it is rendered brittle. Its melting-point is 1064° centigrade. It is very malleable and very ductile, it can be beaten into leaves 95,000th of an inch thick, and a single grain can be drawn out into a fine wire 500 feet long. Its malleability and ductility have rendered it suitable for fine ornamental work, and in days of pomp and pageantry gold textures have always been in evidence. The Assyrian kings wore robes interwoven with gold; the Egyptian mummies are often gilded with gold: Darius, the Persian king, wore a mantle with two gold hawks embroidered upon it. Even in the present day, military and naval and ecclesiastic garments require gold braid.

The Gold that was One of the First Metals Found by Man

But gold, now, is mainly the medium of mercantile interchange, and nowadays gold is not woven into kings' garments, but stamped with kings' faces. It represents material wealth, and thousands of great iron pestles are thudding all over the world to crush it out of the quartz and other rocks which contain it. Yet as a metal it is much less useful than iron or aluminium.

The geological distribution of gold is very interesting. It occurs both in *alluvium*—that is to say, in soil deposited by running water—and in rocks. When it occurs in alluvial deposits it is easily gathered, as grains and nuggets, and no doubt in this form it was one of the first metals acquired by man. All that is required for this kind of gold-mining is just a spade to dig the soil, a trough with a current of running water to make mud of the soil, and a blanket to put along the floor of the trough to catch the heavy particles of the gold as they sink to the bottom of the stream. By such simple means the writer himself has collected gold in New Zealand. There are carvings in Upper Egypt, dating about 2500 B.C., which show miners engaged in washing auriferous sand in hollowed-out stone basins, and melting the gold in primitive furnaces by means of mouth blow-pipes. In India, the El Dorado of the world until the discovery of America, sheepskins were often used to catch the particles of alluvial gold. Hence the well-known legend of Jason and the Golden Fleece. Even now the miners in the mountains of the Caucasus put sheepskins in their sluice-boxes, to catch the gold.

Nowadays, however, washing of auriferous sand is usually carried out in a more scientific fashion. Mercury, which has a great affinity for gold, is often used to catch the gold, and there are various mechanical contrivances to facilitate washing.

How Gold Exists in Some Form all the World Over

Alluvial, or *placer*, diggings, as they are often called, are pre-eminently the poor man's opportunity; and all the great rushes to goldfields have been to goldfields of this description. Not only has the poor man a chance to make a fortune by steady work with his spade and pick, but any day he may find a huge nugget worth thousands of pounds. The "Blanch Barkley" nugget, found in South Australia, weighed 146 lb., the "Welcome" nugget, found in Victoria, weighed 183 lb., and in California a nugget was found weighing 195 lb. Placer deposits are found all over the world—in Cornwall, Wales, Sutherlandshire; in the Rhine, the Rheuss, the Aar; in China, Japan, Borneo, British Guiana, South Africa, North America, South America, Australia, and New Zealand. In fact, there is hardly a country where placer gold is not found to some extent.

One cannot mention gold without mentioning its young cousin silver, an ancient, ornamental, and plutocratic metal. But silver is not so ancient as gold, chiefly because it rarely occurs *native* in nature, but mostly in ores, from which it is difficult to extract,

Gold can be washed out of mud into a sheepskin, but silver requires reef-mining machinery and metallurgical processes.

Silver has a pure white colour and a beautiful lustre, and it has also a soft, plastic character that naturally lends itself to plastic art. It is second only to gold in malleability and ductility. Like gold, it does not tarnish on exposure to moisture and air; but, on the other hand, if the air contains sulphuretted hydrogen, a black film of sulphide of silver forms upon its surface. It resists the action of caustic alkalies, and is therefore used for making chemical vessels to contain caustic potash and soda. It is the best conductor of heat and electricity. Its melting-point is 962° centigrade. Owing to its softness, it is not durable unless alloyed with a little copper. Silver is chiefly used for coins, plate, and jewellery, but it is also used in photography. Like gold, it can be woven into cloth.

THE BASIS OF THE LEGEND OF THE GOLDEN FLEECE

In the days before history, man's eagerness for the precious metals undoubtedly existed, and the perils of these early adventures doubtless gave rise to the famous legend of the Golden Fleece, which has a basis in actual fact. To bring the fleece back to Greece, the Argonauts, under Jason, traversed the Black Sea to Colchis in Asia, and wrested, from a fabulous fire-breathing monster, a ram's fleece of gold. The "Golden Fleece" is not all mere legend, for sheepskins were actually used in the East to catch particles of alluvial gold in the process of washing the mineral.

The principal silver-mines in the present day are in Nevada, Colorado, Bolivia, and New South Wales. In 1909 the output of silver from the mines of Huanchaca, in Bolivia, amounted to 5,591,000 ounces. The silver-mines of San Jose, Bolivia, were once so rich that when the owner's first child was christened the father laid a triple row of silver bricks for the sponsor to walk upon from the palace to the church, and afterwards presented the entire pavement to the sponsor. The silver-mines of Broken Hill, New South Wales, have produced enormous quantities of silver. The principal mine yielded 7,727,877 ounces of silver in 1890; in 1909 the output was 1,718,005 ounces.

Silver naturally leads us to the consideration of quicksilver, or mercury, the remarkable metal which remains in a liquid state at ordinary temperatures, and solidifies only at −39° centigrade. It was a favourite metal of the alchemists, who, indeed, considered mercury and sulphur the father and mother of all elements. It occurs in Nature chiefly in the form of the red sulphide called *cinnabar*, and is easily separated from that sulphide in a pure state.

Mercury readily forms alloys with other metals, and alloys with mercury are usually named amalgams. An amalgam of tin and mercury is used for silvering mirrors; amalgams of gold and silver are used for silvering and gilding; and amalgams of cadmium and copper are used in dentistry.

Pure mercury is used for thermometers, barometers, manometers, and is well known in medicine in the form of "blue pills" and "grey powders." When the red oxide of mercury is heated, it gives off its oxygen, and it was by experiments with this oxide that Priestley discovered oxygen.

Lead, tin, and zinc are useful but commonplace metals whose uses and characters are too well known to need to be recounted.

A CHAIN OF LIVING PLANT-CELLS

All the higher forms of plant life are those with many-celled organisms, the unicellular—or one-celled—animals or plants being quite the lowest in Nature's scale. The fresh-water alga, shown magnified 50,000 times in this striking photograph by Mr. J. J. Ward, is a specimen of the one-celled plant. The whole plant body consists solely of a number of simple cells joined together.

THE MYSTERY OF SEX

The Antiquity of Sex and Its Purpose in Life—Man the Innovator and the Liberal ; Woman the Maintainer and the Conservative

CARRYING ON THE LIFE OF THE WORLD

In the history of life it is clear that absence of sex, and the consequent form of reproduction which we have called asexual, is followed by the evolution of sex, for the purpose or purposes, whatever they be, of sexual reproduction. Let us be quite clear as to this last assertion. The evolution and maintenance of sex, whatever it means, is most certainly not for the purposes of the sexually differentiated individuals, male and female, but it is definitely for the purpose of sexual reproduction, and thus for the race and the future.

What are the advantages of sexual reproduction, for which sex exists, we must in due course endeavour to discover. It is certain that they exist ; and recent work has proved, once and for all, that the greatest of its functions, that of providing new variations and making progress possible, is indeed discharged by it, notwithstanding the confident verdict of one school of workers, to the effect that variation in the offspring exists as much under asexual as under sexual reproduction.

If we are to estimate, in the first place, the importance and the vital depth of our subject, we must observe how widely and consistently the fact of sex manifests itself. Having observed the simple one-celled animals and plants, such as amœba and alga and microbe, we saw that they were sexless, though it remains as a strange omen in our memory that some of the one-celled animal forms have been observed to pair, in a fashion which seems to presage and foreshadow sex, though those creatures exhibit no sex-differences to the closest observation. If now we pass higher up the scale, whether of animals or of plants, we soon encounter obvious and typical sex, and are clearly taught that life has deliberately and consistently shown itself in sexual form, male or female, throughout all its stages, from a very remote time, along both the animal and the vegetable road.

But until very recent years no one suspected how far down in the scale sex was to be found. When we are dealing with creatures of the amœba pattern, which only consist of one cell, and which have no *body* to display differences of sex, as the bodies of higher organisms do—creatures which are indeed all race, and cannot be counted as individuals at all—we do not find it credible that sex should yet have come into being. Twenty years or less ago any biologist would have said that, before we can discern sex, we must at least reach the stage of the many-celled creatures. As these evolved we should find that they show themselves in two forms, male and female, according to the contrasted type of their bodies, and of the germ-cells which they produce—or which are produced in them. But sex in one-celled creatures—never !

The present writer well remembers the incredulity with which he read the first accounts of the changes in form and the life-history of the malaria parasite—a minute, one-celled animal organism found in the stomach of certain mosquitoes, and in the blood of men suffering from malaria. Observers declared that there were stages in the life of this creature when two contrasted types of cell were to be found, and these contrasted types, as their form and behaviour showed, were male and female. However, actual observation must convince the most incredulous that the facts are so, for they can be directly observed under the microscope and must be accepted. We now know that there are many kinds, no one yet knows how many, of one-celled organisms which display sexual forms; and we have to realise that sex is thus vastly older and far more deeply rooted in the very nature and necessities of life than we had ever supposed.

These new discoveries in the realm of the microscopic and most humble forms of life thus increase our estimate of the importance of sex and its function in the living world.

There is, however, another question which we must answer before we are content to infer the importance of sex from its antiquity and long persistence in the history of life. It is a question which primarily concerns the biologist and student of evolution, and which he must answer on the evidence, without a thought of any other interest.

Does Sex Become Less and Less Important as Life Ascends?

But the answer to this question involves us instantaneously in the very thick of the most topical and controversial and angry of political arguments, for it obviously involves the character and destiny of womanhood and its functions in human society, present and future.

The question is this. If sex is a very ancient attribute of life, and is found among very humble and insignificant species, may we not find that the true course of evolution has been, is, and must be to control, narrow down, and even substantially obliterate sex-differences? The very argument as to the importance of sex, which is derived from its newly realised antiquity, is also an argument, or may be made one, in favour of the view that, as life ascends, sex ought to become less important; and, in short—for we are on thin ice here, in our impartial scientific inquiry—that women should have votes and should compete with men in every sphere of human existence and activity.

Our business here is to do justice to the scientific truth, and on no account to let it be mixed up, much less soiled and dishonoured, by the passions and prejudices of men and women, least of all by the most disastrous and abominable of passions, sex-antagonism, which works foul mischief in human life equally when directed by men against women or by women against men.

Nothing can Endure which is not Based on Sound Argument from Nature

Also, the man of science, in stating the facts as he sees them, requires to protect himself and them from those who proceed to argue therefrom, on any side. It is necessary to argue from scientific facts. The man of science declares, indeed, that nothing is true nor durable nor ultimately useful, in individual or national life, which is not based upon sound argument from nature. But his experience sadly teaches him that fact and interpretation are constantly confounded, and that he no sooner states a fact than people seize upon it for their own purposes, and often assert conclusions therefrom which the man of science knows to be dubious or even false. Here, therefore, the facts of the evolution of sex are stated, as is our present duty; and all conclusions based thereon by all persons who have already made up their minds are disclaimed as without warrant in science.

The contrast between the sexes is most marked among insects, where the rule is that the males are smaller, weaker, shorter-lived, and grossly inferior in instincts and what we may perhaps call morals, as bees, ants, and wasps, to take the most celebrated cases, abundantly illustrate. It is true that sex-differences among vertebrates are not so great as among the insects, and it has hence been argued that sex-differences are diminishing as life ascends. This is to assume, together with many other arguable points, that vertebrates are descended from insects.

That was not the case. The insects and their evolution are peculiar, apart, notable, and admirable indeed, but incapable of proving what many attempt to prove, though they do illustrate truths of general import. We do not know where the insects are going, nor what, so to say, they are after.

The Effect of Sex Difference on the Achievements of Insect Civilisation

We do know, however, that in a host of respects their capacities, and especially their social and racial life and organisation, are vastly superior to ours; and the argument from the insects may very well be, in reality, that if we are to attain a higher, less wasteful, more admirable civilisation, we must have not less, but more, differentiation between the sexes, for there can be no doubt that the achievements of insect civilisation entirely depend upon, and involve a far greater measure of, sexual differentiation than anything to be found among the vertebrates. Observing, then, that the argument from the insects cuts both ways, and requires more analysis if it is to serve the cause of truth, we may leave them on one side, and proceed to the evolution of sex in the line of animal progress, at the extremity of which stands man, the pioneer, himself.

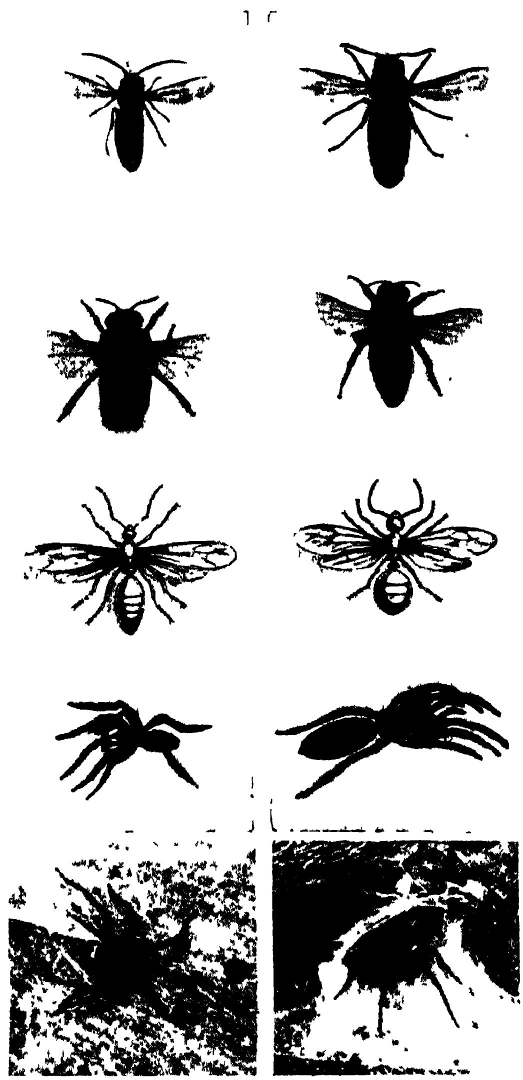
The evidence is clear—much more so now than even twenty years ago—that the open road of life has been taken by forms in which sex has been progressively more, and not less, important. In short, sex is an early instrument of life, early because essential, as it would appear, to life's purposes; and the instrument becomes more powerful, more delicate, more subtle in its

work, and ever more absolutely essential to the advance of life, as life advances. This is the evidence afforded by a survey of living forms in general, not animal only, but also vegetab e ; and it emphasises the importance of sex, with all the force of immeasurable experience, against those who say, in any connection or for any purpose, that the trend of evolution is towards the obliteration of sex-difference.

In the judgment of those who have thought longest and most seriously on this question, the demands of further evolution require not less differentiation of sex, but a juster appreciation, by men and women alike, of the natural, indispensable difference between them, ineradicable save at the cost of the race itself. Thus, if the history of sex is to be trusted, there will always be room and need for a certain feminism, but it will be a doctrine which proclaims the rights of woman to be a woman, not to be a man.

It were well to return quickly from these questions of interpretation to the facts; but the facts could not be appreciated until we had definitely satisfied ourselves of the importance of sex, as proved by its almost incredible antiquity, very nearly coæval with life itself; by its persistence, its constant exhibition in vegetable and animal life alike, its conspicuous development, and evidently indispensable function, in the highest achievements of life—the societies of insects and the societies of man.

It has already been argued that sex exists for the purposes and the advantages, still awaiting complete discovery, of sexual, as distinguished from asexual, reproduction. Before we study the essential facts of that process, we should endeavour, by a survey of male and female forms, as the world of life displays them, to state what is the essential difference between the sexes. It needs little looking to show that the difference is not one of size or colour, or intelligence or muscularity, or external form, or any other of those things which most readily occur to us. These differences exist, but there is no constancy in them, for sometimes the male, sometimes the female, may have the advantage, in these or in a host of other particulars. The essential difference lies deeper; and we owe its first adequate recognition to the two distinguished Scotsmen, Professor Patrick Geddes and Professor J. A. Thomson, whose famous book on the "Evolution of Sex" has established the matter once and for all. They showed the essential difference between the sexes to be that the female spends a less proportion of energy in the present and for herself, as compared with the proportion she stores up for the future of the race; while the male keeps and devotes less of his vital powers to the future of the race, and spends more upon the present.



THE SEXES IN INSECT LIFE

In insects the contrast between the sexes is usually most marked, the general rule being that the males are smaller, weaker, short-lived, and grossly inferior in morals and instincts. These pictures show both sexes of the wasp, the bee, the ant, and two kinds of spiders, the female each case being on the right.

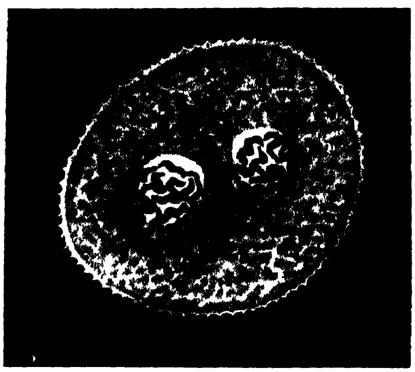
One cannot eat one's cake and have it. Every living individual has a certain amount of energy to use. If the law of the conservation of energy means anything, and if it applies to living beings, as it assuredly does, it means that they must in every case make some adjustment between what they spend

upon themselves and what they keep to spend upon the future. The physicists teach us to think of energy as either *potential* and stored up, or *kinetic* and in action. Now, the essential and necessary difference between the female organism and the male organism is that, though both have themselves to maintain by present action and expenditure, and though they have the future to contribute to and provide for, by storing up energy, and not spending it, the ratio of expenditure to thrift is higher in the male and lower in the female. The male spends, moves, seeks, destroys, invents, obtains; the female saves, stays at home, is patient, constructs, rejects, maintains. He is the innovator, the liberal; she the maintainer, the conservative. The theme is a great one; but those who desire to acquaint themselves with its entirety should consult the famous, compact, and readable volume in which it was first established. Our present business requires the noting of only one further point.

It is that these essential and general differences of sex, clearly displayed by normal and typical members of either sex in any species, are also displayed by the germ-cells which it is the essential business of the individual organism to produce and protect for the supreme need of reproduction and race maintenance. When we come to study Weismann's work we shall see that, in a special and limited sense, germ-cells are perhaps not produced by, though produced in, individuals. Meanwhile we may speak in the ordinary language.

Observe that the difference between the sexes, as defined above, is no more than a matter of proportion—that the ratio of self-preserving to race-preserving expenditure is, on the average and typically, higher in the male organism than in the female. But obviously we require also a clear understanding of what it is that makes any given organism male or female respectively. The answer is positive and fundamental. A male organism produces one kind of germ-cell, and a female organism produces another kind. Whatever organism produces male germ-cells is a male, whatever produces female germ-cells is a female. Again, the great principle is true—that by the fruit is the tree known.

Now, the point we require to observe is that the difference between male and female organisms, already defined, is shared by their respective fruit, the germ-cells. The rule, which we find equally and indifferently illustrated in the case of the highest species and the lowest, animal or vegetable, is that the male germ-cell is active, mobile, and usually smaller; while the female germ-cell is passive, stationary, and usually larger, because it usually has associated with it a lesser or greater quantity of stored-up energy, in the form of food for the young life that is to be. This we see in the bird's egg, in the ovary of a flower, and in a thousand other cases. We do much less than justice to the principle discovered and elucidated by Geddes and Thomson unless we complete the argument by recognising that the great, the only unquestionable and cardinal, difference between the two sexes is to be found not merely in the bodies and behaviour of individuals of the two sexes respectively, but also nearly always in the nature and behaviour of the germ-cells which those bodies produce.

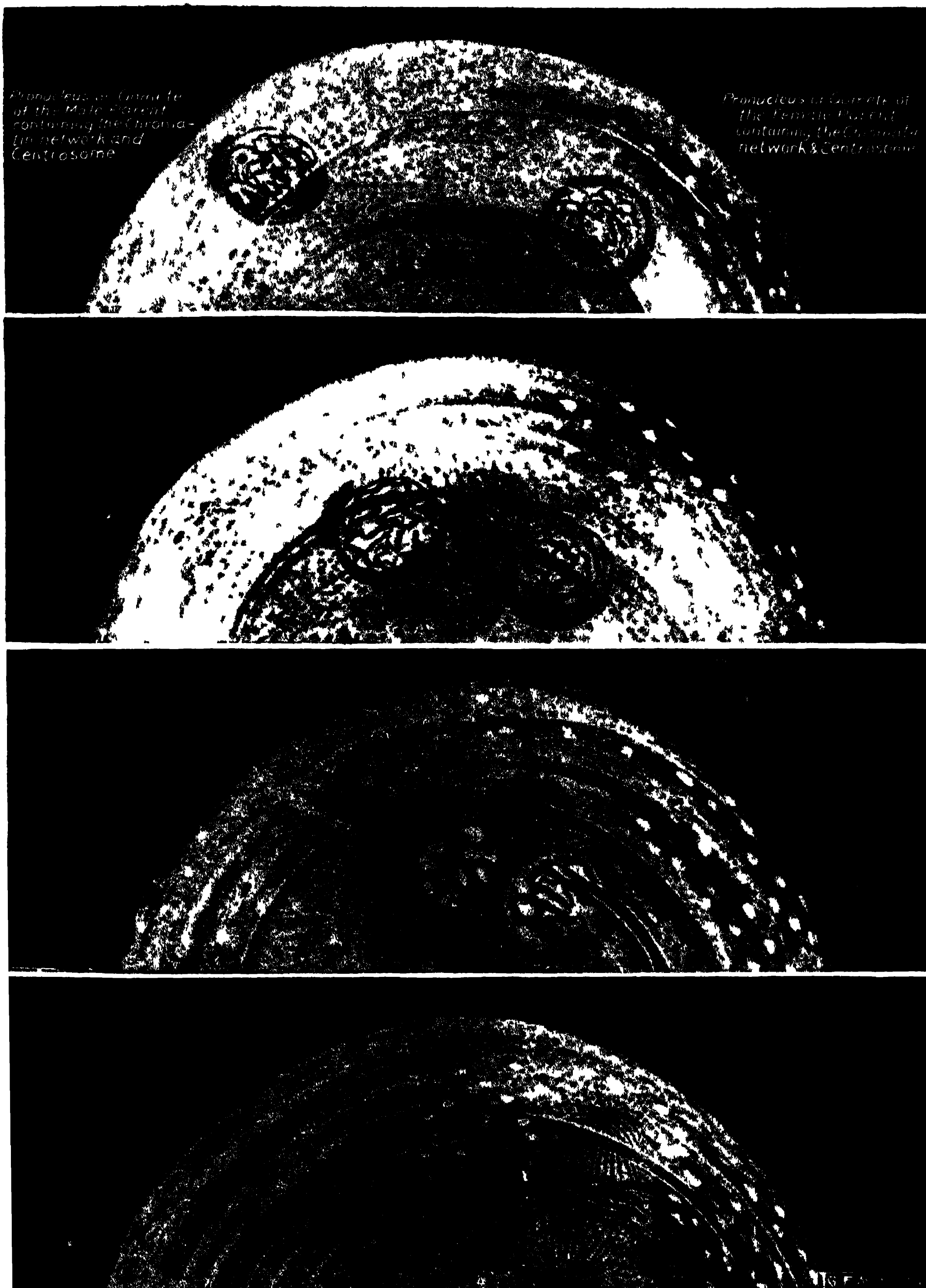


A GERM CELL OF PLANT-LIFE

A section across a pollen grain, showing the nuclei which start the fertilisation of plant-life

We must beware of a most excusable confusion which is almost general among not only students but also the less recent expositors of this subject. When we talk, as we do, and as science will ever increasingly do, of male and female germ-cells, we must understand that we are referring to the parent, the organism that produced them, not to the organism which they will produce. A female germ-cell is so called because it has certain characteristics, which are also to be found in the individual that produced it. But this germ-cell might well contain maleness, for it may become a male individual. Mothers have sons, we all know; and if we think about it at all—which is very improbable, with new editions of the evening papers coming out every moment—we probably suppose that the maleness of the son is derived from his father, and the femaleness of a daughter from her mother. The case of any species which shows "alternation of generations" disproves this, for there we find offspring of both sexes being produced by an individual which is female, if anything; and the production of drones by the unfertilised eggs of the queen bee is conclusive.

THE BIRTH OF PLANT AND ANIMAL LIFE



These pictures represent the astonishing process by which is produced the first complete cell of plant or animal life. Shown here largely magnified, these cells are actually invisible specks, yet holding within themselves all the potentiality of life, all the characteristics of the individual, with its infinity of variations. In the top picture the cells are seen approaching each other, and, as they come together, the centrosomes of the two cells leave the cells, and, as shown in the second picture, begin to develop the achromatin filament which ultimately links them, as in the third picture. The chromosomes attached to each filament now combine to form the first cell of a new organism, and the union of the two cells has thus created a power that neither had before—the power of building up a new individual. The new cell has also the power of reproducing itself, as shown on page 536, until the organism is completely built up.

In this remarkable case, which upsets all our preconceptions, and gives us entirely new and lasting conceptions instead, we find that the female germ-cells produce males so long as they do all the work alone, but that if the female germ-cells be fused with male germ-cells, the resulting individuals are female! We ought therefore to know what we mean, and what we do not mean, when we speak of male and female germ-cells, and we are to be prepared to find a female germ-cell carrying the quality of maleness for the individual which is to be formed therefrom, or a male germ-cell carrying the quality of femaleness.

The Central, Essential, and Creative Fact of All Sex

The confusion of language is unfortunate, for it seems absurd to speak of that as a female germ-cell which is indeed none other than an immature male individual, but the confusion is the penalty of trying to say things too quickly. To be accurate, we should say, not "female germ-cell" or "male germ-cell," but germ-cell from a female or a male organism respectively—ovum or sperm, if we happen to refer to animals; ovum or pollen-cell, if to plants.

And now we come to the central, essential, mysterious, creative fact of all sex, which is that sex exists for sexual reproduction, which consists in the fusion of two germ-cells, male and female, in such a way that they become a single cell, which is the new individual, and may itself be of either sex. The oak, the whale, the lobster, each is at first a single cell, thus formed, and so also is the body of man.

The supreme, creative act of cell-union is effected by the fusion of the two nuclei, which are the essential parts of the male and female germ-cells—gametes, or marrying cells, we should now call them. But these gametes must not unite until they are mature; and their union will be unintelligible to us until we look at the process which has been known for many years as the maturation of the germ-cells, and is now known as *gameto-genesis*—the genesis of gametes.

The Process within which All the Facts of Heredity Lie Hidden

Within the details of this process the facts and methods of heredity are hidden, and now, indeed, partly revealed; and that is the best of reasons why we should understand their nature as soon as possible.

The body of an individual, male or female, of any typical species, animal or vegetable, does not contain an indefinite number of ripe or mature germ-cells, but a number of cells, between them constituting what we so often refer to loosely as the "germ-plasm," which are engaged, throughout the reproductive life of the individual, in preparing gametes fit for union. This is gameto-genesis, and it is a most complicated and elaborate process of cell-growth and cell-division, which is being gone through continuously by the reproductive or racial tissues of all the higher animals and plants.

But the essential phenomena of gameto-genesis are only to be observed through the microscope, and they are unmistakable and purposive almost beyond vital processes in general—which is saying a good deal. What we find in both sexes is essentially this: cells in the racial tissues—found in the reproductive glands of animal or plant—divide and divide again, until one final division, which is different from all preceding it, and, indeed, from all other processes of cell-division found elsewhere. The peculiarity of this last division of the mother-cells, as they may be called, of the gametes, is that the chromosomes are not split and divided among the daughters, as they are in all other cases.

The Amazing Process upon which the Progress of Life on the Earth Depends

The very last cell-division, the result of which is the final gamete, male or female, as the case may be, ignores the ordinary rule, and involves an allotment of the chromosomes of the nucleus among the daughter nuclei, so that each daughter nucleus gets half of the number of the chromosomes in the parent. Suppose, thus, that twenty-four is the normal number of chromosomes formed in the dividing nucleus of any cell of the body in the species in question. We know how, when ordinary division occurs, and new cells are formed, the chromosomes are split up, so that the new cells have as many as their parent.

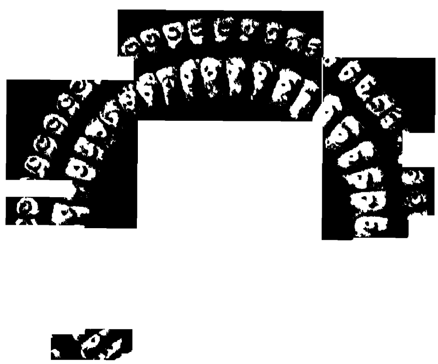
But in the final division of the cells in the reproductive tissue—the division of which the progeny are the gametes themselves—the chromosomes are distributed, so that each final or "ripe" or "mature" germ-cell has one half the number of chromosomes proper to the species. In the case in question, therefore, each gamete, whether formed in the male or in the female body, has only twelve chromosomes composing the chromatin of its nucleus, instead of twenty-four. And, so far as we can judge, the whole amazing process of gameto-genesis, or germ-cell formation, as we see it in the reproductive glands of animal or plant, exists above all to effect

this remarkable "reduction of the chromosomes," as it is called.

Whenever, then, we examine a germ-cell or gamete, of any individual of any species, and find that its nuclear chromatin consists of, say, twelve chromosomes, we shall not declare that twelve is the characteristic number for the species in question, but shall expect to find, and shall find, twenty-four in all the cells of its body but these. Several of the numbers formerly stated to be characteristic of the corresponding species require to be doubled, as they are the numbers found in the germ-cells, in which the "reduction of the chromosomes" has halved their number.

It need hardly be said that what we can only call the object of this reduction is to create a nucleus male or female, so constituted that it requires the addition of another similar nucleus, female or male, to make it complete, after the fashion of the species to which it belongs. The new nucleus has its complement of chromosomes; and its division, and the innumerable divisions of its descendants, to make the body of the new individual, are conducted so as to maintain this number throughout.

Within the last few years the discovery has been made that these rules are not observed in the case of the disease called cancer, which consists of an abnormal cell-growth in the body. There is evidence to show that the process of karyokinesis in the cells of a cancer is wholly unlike that of normal body-cells, and is more allied to the type of nuclear division which we see in the formation of germ-cells. The students of cancer are agreed that this fact is fundamental, and are now using it, with definitely approaching success, as a clue in the search for the causes which lead cells of the body to behave not as cells of the body should, but rather like cells of a new and alien generation. This is not the place to discuss the subject further, but the facts are profoundly instructive in teaching the unity of science amid all its multiplicity, and the fashion in which remote lines of research are bound together.



THE BEGINNING OF LIVING STRUCTURE

Cell division, shown on page 535, builds up new life combination builds up structure. Countless billions of cells arise in the body of a living thing, joining together to form its various parts. This picture represents cells beginning to assume the rudimentary animal form.

The gametes, male and female, now unite. The circumstances are infinitely various, but the essential fact is one and the same, whether we study the fertilisation of a plant, the shedding of the ova of a fish and their fertilisation in the water, or the various means by which the gametes are yoked, to form one cell, in the case of the higher animals, and many of the lower animals too. It is sufficient to note that, in every species where the mother sustains the new life within her own body, and above all in the case of the mammalia—the best representatives of the animals which bring forth their young alive—the fusion of male and female gametes occurs within the body of the mother, where the development of the new being can take place in the greatest certainty and safety.

The essential fact in all cases is not the conditions or circumstances of the cell-union, but the fact that it occurs, and that the fusion of the nuclei is of the most perfect and intimate character. The new being, formed by this yoking, or pairing, is called the *zygote*—that is to say, the *yoked*—and all our studies up to this point find their conclusion in the fact that the zygote, as represented by the single nucleus—with a cell-body outside it, of course—from which all the development of the future springs, is equally constituted of the nucleus derived from its father and the nucleus derived from its mother. That is the meaning of the whole process. No sex-antagonism, no vaunting of one sex over the other, is here; no warrant for anything but sex-harmony, co-operation, and equality. The new nucleus is constructed equally from paternal and maternal material; and the fusion of the chromosomes from these two sources is intimate and detailed beyond the power even of the highest microscope to observe.

The chromatic network of the new nucleus is thus, though single, yet double; it is of

double origin, for paternal and maternal substance are yoked in every portion of it. When it divides, which it does in the fashion now familiar to us, its chromosomes, as they split, each carry paternal and maternal stuff to each daughter-cell, and so on to the end. Every skin-cell of the myriads which we shed every time we wash our hands contains a nucleus of which one half was derived from our mothers and the other half from our fathers. A generation ago Huxley said: "It is conceivable, and indeed probable, that every part of the adult contains molecules derived both from the male and from the female parent; and that, regarded as a mass of molecules, the entire organism may be compared to a web, of which the warp is derived from the female and the woof from the male." To this most admirable speculation, now justified, Professor E. B. Wilson, author of the standard treatise on the cell, adds the comment: "What has since been gained is the knowledge that this web is to be sought in the chromatic substance of the nuclei, and that the centrosome is the weaver at the loom."

Fertilisation, or the process of making fertile, is the old and intelligible name for that which enables a new life to develop. The gardener and the agriculturist, the botanist and the student of heredity, have long thought of the elements derived from the male organism as somehow making fertile the life which is latent but unrealised in the cell of the female organism. These cells in animals or plants we may call by the old name of *ova*, and we assume that the ovum waits for the coming of the pollen in the case of the plant, or of the spermatozoon in the case of the animal, to make it fertile. The implied idea is that the male influence is a fertilising, stimulating one, but that the mother is the real parent.

The contrary idea is scarcely less familiar in men's thinking on these matters. Arguing from the facts as they appear among the higher animals, for instance, men have argued that the father is the real parent—as the transmission of surnames in most human societies suggests—and that the mother is only the host, vessel, trustee, nurse, temple of the new life.

The facts directly contradict both theories. Neither the mother nor the father alone is the real parent, as the above theories implied; the new nucleus is formed, with strict and most minutely detailed justice, of elements equally derived from both. So far as hereditary transmission is concerned they are absolutely equal. Yet it is worthy of note that, in most cases, the female gamete and the male gamete each bring with them something, for the service of the new life, beyond what actually goes to the constitution of the new body. As a rule, the female gamete brings with it a store of nutriment, which, in the case, for instance, of the bird's egg, may be amazing in bulk. This nutriment is not the gamete, but accompanies it. The vast majority of ova are more or less supplied with this store of energy; and we note the exact correspondence of the facts with the theory of Geddes and Thomson that the female sex stores and conserves, rather than spends.

FERTILISATION IN SIMPLE PLANT-LIFE

Our knowledge of the conditions under which the simple water-plants called algæ pass through the critical stages of their life-cycle is still very imperfect, but this photograph represents what happens as far as we can observe . . . Not possessed of the ordinary methods of fertilisation by means of pollen and pistil, the alga casts its spores into the water, where they rest on the mud.

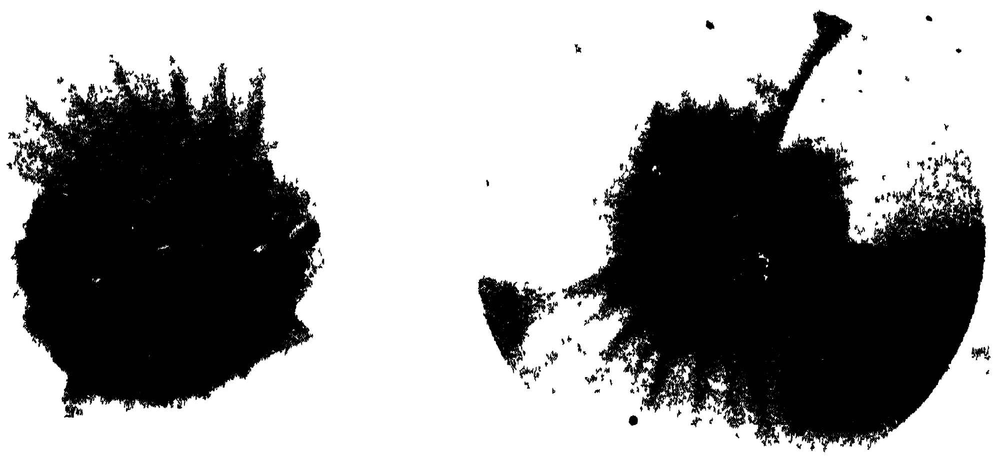
Just so do we find that the male gamete, pollen-cell, or spermatozoon brings with it something which is more than its nuclear chromosomes. It appears that, at any rate in many observed cases, the female gamete has lost its centrosome—that curious body which lies beside the nucleus of a typical cell, and starts its division. The ovum, or female gamete, to use the more definite term, has a nucleus, but no centrosome.

The nucleus could not divide if it would, for the centrosome, we saw, is the initiator of nuclear division. Now, when we study spermatozoa very carefully under the microscope, we find that, in a wide variety of

species, they contain, in addition to the essential nucleus, a minute particle which is really a centrosome. That centrosome of the male gamete becomes the centrosome of the new cell, formed by the union of male and female gametes. When the cell divides and proceeds to develop into the new individual, it is the centrosome, derived from the father, that starts the process, and keeps it going, inventing, stimulating, spending, moving ; and it is the store of food brought by the female gamete that makes the first activity of the centrosome possible.

We see, then, how exactly—nay, how exquisitely—the functions of the two sexes are co-ordinated in the business of reproduction, and how their mutual relation when fused becoming a new life, to carry on the race and to further the great purpose of the world.

Lastly, we realise, as never before, that every individual which has been formed by the process of sexual reproduction is a double being, formed of a part derived from each parent. The name of zygote, which modern biologists have now agreed to use, exactly expresses this truth—that the new individual is twofold, made of two parts which are yoked to form one. This statement in itself may seem of small importance but when we attempt to unravel the facts of heredity we discover that this double character of every individual, one as an individual, but two from



THE SEXES IN PLANT-LIFE—MALE AND FEMALE BEGONIA FLOWERS

These two flowers on the same begonia plant show the difference of the sexes in plant-life. That on the left is the male flower, and in it we see the stamens containing the fructifying pollen or fertilising powder. On the right we see the stigmas which receive the pollen transferred by insects from the male flowers. These stigmas are connected with the ovary, the vessel in which the seeds are formed.

and service, in this world of the microscopic, correspond with the mutual relation of the sexes in that larger world which we call the life of mankind. The old idea, so much thought about for thousands of years, that man is the microcosm, or little world, corresponding to the macrocosm, or big world, is abundantly paralleled when we compare a typical marriage in the world of man, the bride bringing her dower and her patience, and the groom his energy and courage, with this marriage of the gametes, the one with a capital of food, and the other with the centrosome and its initiative, each in the eyes of Nature equal, each impotent without the other to create the future, yet the point of view of ancestry and offspring, is the master-key to the problems of heredity, as Mendel taught an unlistening world from his monastery garden in Brünn nearly half a century ago—he whose incomparable researches have proved to be of such unique value to the student of life in the twentieth century, as we have read elsewhere in this work.

Meanwhile we are confronted with the new nucleus, the single cell or zygote, which may develop into an oak or a whale, or a new individual of any species ; and in its tiny and well-nigh inscrutable countenance we try to read the incredible and miraculous story of Development.

THE GARDEN A NATION COULD LIVE UPON

Prince Kropotkin estimates that by scientific gardening it is possible to produce in one square mile all that is needed for the maintenance of 600 people. At this rate, by intensively cultivating the area shown, as a garden in this map of Great Britain, it should be possible to produce sufficient to supply the needs of the population of the United Kingdom, not only in food, but in clothing also.

THE POWER OF THE SOIL

The Scientific Cultivation of the Earth and its Extraordinary Possibilities for the Farmer

AN INEXHAUSTIBLE MINE OF WEALTH

We have seen how full of life is the soil, how it is both a manufactory and a chemical laboratory. A pinch of top-soil contains hundreds of bacteria, who are performing many functions, too subtle even for the chemist. They are not only working at the stuff already in the ground; they are even extracting material from the air, as in another way do the plants, whose growth they make possible. Again, this little bit of soil is probably an amalgam of some ten or more chemical substances or elements, of which most are necessary to the plant. We have heard lately some alarming accounts of the extinction of one of these chemical substances, the compressed carbon which we call coal. But much more alarming than the loss of coal would be the extinction of the fertility of the soil, this top-soil in which so much is going on; and nothing is more vital to know than the prospects of this fertility.

From time to time men of science, among them Sir William Crookes, have prophesied what may be called the end of the soil. They pointed out that if it once became exhausted of nitrogen, starvation would stare us all in the face. Happily, recent discoveries and researches go to show that the soil is a mine of wealth which can never be quite worked out.

No doubt our farmers, if they are good farmers, put back into the land every year, or every other year, at least as much as they take out; and unless they do this, the earth, immediately sensitive to the neglect, returns smaller crops—the yield of the mine falls. Nevertheless the yield never quite ceases.

There is an amazing patch of ground in Hertfordshire to which men make pilgrimage almost as if it were a shrine. No year passes without a visit from colonial and foreign farmers, especially Americans, one of whom declared that Americans have learnt more from this field than from any other agricultural experiment in the world. The patch is more than useful. It stands as a sign of proof to man that the earth will always be capable of bearing food. Every autumn for sixty years that plot has been sown with wheat, and every autumn a crop has been reaped and garnered. Not a teaspoonful of manure has been put on the plot; and yet the mine continues to yield its golden harvest.

For many years—indeed, for nearly a generation—the harvest has not decreased at all; and it is still as large as the world's average crop. This is, of course, a small yield; very small as compared with our cultivated acres. Still, it is a crop worth reaping, and it does not diminish. It is now thought that it will never diminish; and that is, in itself, a sufficiently wonderful fact.

The plot is like the widow's cruse; and its replenishing is as wonderful. A little wealth stolen from the air by the blades of corn passes down the stalk into the roots; and so into the ground. The rain brings down with it a little wealth. Perhaps birds and flying leaves and casual weeds add a little more. At any rate, somehow or other, nitrogen, the first agent in growth, is year by year restored or manufactured in the ground, and no other necessary chemical is quite exhausted. In early growth the wheat plants look as strong on that plot as on the best fields, but that is because the wheat-seed itself supplies the first food to the plant, just as the egg supplies it to the growing chick. Later, the short straw and dwindled ear prove that the ground is poor, but the hopeful fact is that this poverty does not seem to be progressive. There is certainly no sign at present that the starvation period once predicted will ever be reached.

This Hertfordshire plot may well be compared with the plains of virgin soil, often, but wrongly, called inexhaustible, that make the chief wealth of Canada and other Western, and indeed Eastern, cornlands. In these you can test the amount of wealth—that is, plant-food—as you can test the seam or veins of a gold-mine. For centuries vegetation has lived and died there; and each plant has taken its food from the sun and air and rain, and stored it up in its own tomb. At the same time, those beneficient bacteria or flora of which we have heard have manufactured the raw material of the dead plants into food of a form digestible by plants. Canadian farmers have the stored wealth of those centuries to draw upon; and as one layer becomes exhausted all they have to do is to plough deeper. Ultimately, perhaps, they will be forced to dig down for this natural manure and spread the lower soil on the upper, exactly as in the mines they must descend to lower levels. But so vast is the store of food that in some areas it will take centuries to exhaust it—that is, to bring it to the stage which almost all our land in England reached long ago.

The Manure that Makes England's Soil Richer Every Year

In England we possess this old plant life, but it is in the form of coal, which was called "bottled sunlight," or of peat, which is vegetable matter unconverted or unmanufactured into plant-food. But the upper, or surface, soil of England has long since lost what may be called its natural fertility. In other words, the reserve of ready-made or, so to speak, predigested plant food, such as is found in loam, has been used up; and though the ground will always produce something, its fertility in the larger sense may be said to depend almost wholly on the manure added to the ground. It is, however, worth noting that in some places English land is growing richer as surely as Canadian land is growing poorer. This is the advantage of what is called intensive cultivation, and this is much more common than it is usually thought to be. Wherever hops are grown, or, shall we say, such fruit as raspberries, strawberries, or logan-berries, much more manure is put into the ground than the plant can use; and these soils grow richer and richer, like well-fed gardens. In so-called French gardens, which are the most intensive forms of cultivation ever designed, the old soil is often sold at high prices, and nearly all of it consists of decayed vegetable matter not used up. So it may come about that we in England use our coal very much as in Canada they use the soil. With the money made by selling it we buy cotton cake or linseed cake, which are given to stock which supply the manure, which makes English soil as rich in its way as the virgin soils of the great North-West, or of Siberia, the cornland of the future. Even our grass fields are accumulating wealth; though they knew it not, the many farmers who let their ploughland go out of cultivation in the period from 1890 to 1900, because it did not pay to grow wheat, were allowing the fields, in some small measure, to accumulate riches.

How the Sandy Tracts of Belgium have Been Made Fertile

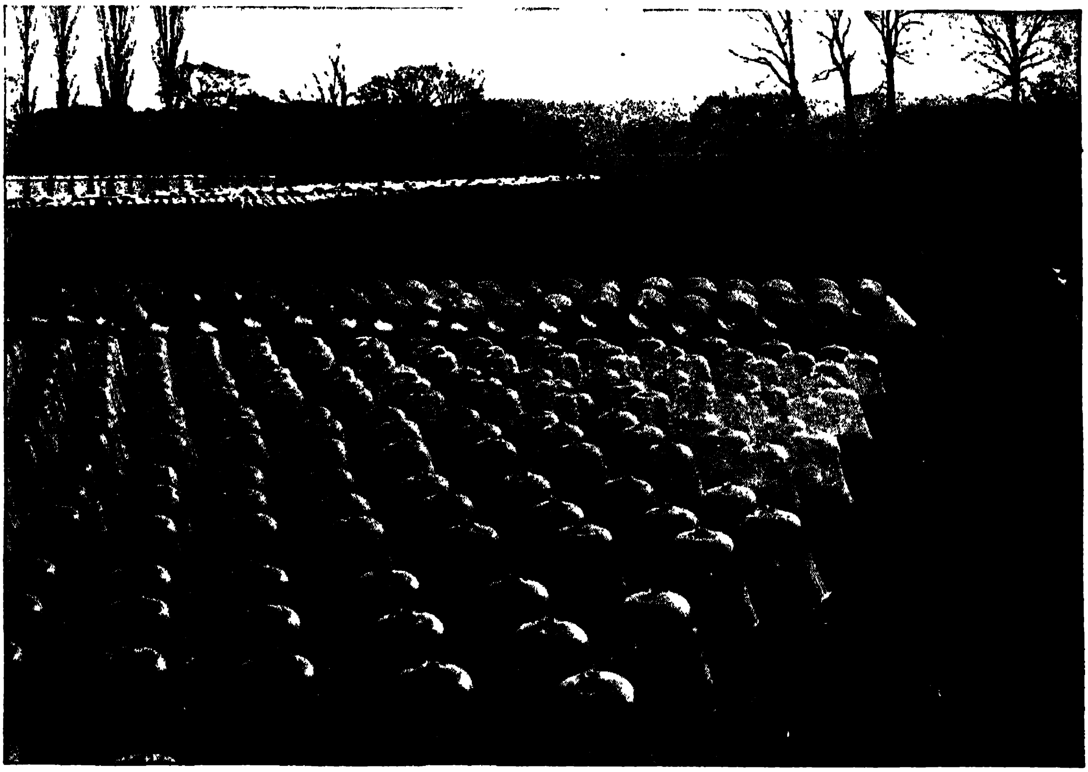
A very striking example of the many ways in which the earth shows its facility for becoming fertile has recently been recorded in Belgium, where the land is as carefully cultivated as in any country. The villagers in some sandy tracts which would only grow fir trees kept a great number of hens which were allowed to run at will in the open pine-woods. One day an investigation of the soil revealed the surprising fact that it had changed its character altogether. It had become genuinely fertile. The trees were grubbed up; and to-day some of the very best fields in Belgium, fields which will bear a succession of crops throughout the year, are to be seen where some few years ago stood nothing but firs and pines. Partly the pine needles, but principally the hens, had enriched the sand, and bound its loose granules into a proper mould. In this way, too, the wheat or maize produced by the fertile soils of new continents may give new fertility to the barren lands of an exhausted region.

We have been speaking of the richness of soil in organic or vegetable matter. But it has also mineral wealth; and here we are only just beginning to understand how very rich even an inferior soil may be, how it may resemble the widow's cruse, or how, like the sea, it remains rich in spite of the millions taken from it year by year.

The Mistake Farmers Make in Letting Land Lie Fallow

An interesting example may be taken from a comparatively new discovery in the art or science of farming. Each crop takes its sustenance from a different layer, as it were, of the soil; some plants root deeply, some are scarcely covered by the soil. It has been found therefore that very much larger crops may be grown to the acre where a mixture of crops is sown.

In Denmark, the great dairying country, where, above all things, fodder for the cows is necessary, such mixed crops as peas, wheat, and barley are grown together with very good results. Not long ago it was a much commoner practice to leave fields fallow—that is, idle—in order that they might recover both wealth and a certain sort of consistency. This is still done on the heavier soils, but the growing habit is very much opposed to leaving any land fallow. The very contrary is practised. Instead of letting the soil lie idle, the best farmers—those who make the most money more harvests of ripened grain can be reaped off the same ground within one summer. Our English soil and climate cannot rival those of Nairobi, but they can do similar, if not equal, wonders. Lucerne, known across the Atlantic as alfalfa, can be reaped three times a year in England, giving each time a heavy crop; and this deep-rooted vetch, which is steadily increasing its area in England, gives as good an instance as any of the rapid manufacture of food by earth and air, which ever co-operate fruitfully for the profit of living creatures.



THE FRENCH SYSTEM OF SCIENTIFIC GARDENING UNDER GLASS

The French intensive system of agriculture intensifies the light and warmth of the sun by means of glass jars. By means of this system, and by the application of modern discoveries as to soils, plant constituents, and manures, it is possible to raise exceptional crops from a given patch of ground for an indefinite period.

This photograph was taken at the Burhill French Gardens, Walton-on-Thames.

—practise what is commonly called catch-cropping—that is to say, they do not let the land lie idle even in the winter months. They make the land yield them a crop between the reaping of the grain in autumn and the sowing in late spring.

The land, even in England, is ready to pour forth wealth. In some favoured regions, for example, along the East Coast of Africa, the richness of the soil, the heat of the sun, and the moisture of the air are such that the plains are a sort of greenhouse or forcing-frame, in which germination and growth are so rapid that two or

What a picture of the vast energy of these two co-operators is offered by a field of maize, another crop that is growing rather more common in England! These great plants, with a stem thick as a young tree, with the broad, waving "blades" and the club heads of grain, grow from eight to twelve feet high in thick ranks that suggest a tropical forest. They produce grain a hundredfold; their stems and leaves are rich in all manner of chemical products.

We may taste the sugar in the stems as distinctly as the starch in the grain. They have breathed in the sun, and compounded

THE GROWTH OF A PLANT IN THE GROUND

The pictures on these two pages represent the gradual growth of plant life. In the first picture the withered pod of a bean is shown opened, the beans having fallen to the ground. The autumn rains wash these seeds into the crannies of the earth, where they are speedily covered by the loose mould and so washed in by the rain.. Thus the seeds lie dormant during the winter, but with the coming of

SIX STAGES IN THE LIFE OF A BEAN

spring we see the first processes of germination. The root goes forth in search of nourishment, and the leaves go to seek the sunshine. No matter how the seed lies, the root always tends to go downwards and the leaves upwards, as shown in the two small pictures. In the last picture the plant is established in the soil, and the leaves are mature, while another bud is forming for further growth.

carbon, they have devoured the minerals of the earth sufficiently to leave, if the seed were burned by fire, a heavy ash of many constituents. And year after year, without any intermission, such produce comes forth, so that the wealth received from each patch would, if the crops could be piled up, reach out of sight. Truly earth and air have worked together to some purpose. Of course, much of this great accomplishment is due to yearly additions of manure to the soil, so that some people almost regard the soil as little more than a sort of basket to hold manure. But it is pertinent to remember that the original and derivative meaning of manure is handwork. It meant at first nothing more than hand cultivation; and few people quite realise how much tillage by itself can do, or, rather, how much the soil can do if it is tilled without being treated.

That wonderful plot at Rothamsted of which we have heard is able to produce this wheat crop year after year for this apparently indefinite period chiefly because it is carefully cultivated. It is given manure in the sense of the Latin word from which manure is derived—it is given "handiwork."

The Tilling of the Soil that Makes for Its Fertility

Alongside this wheat plot is another which illustrates more distinctly yet the amazing persistence of the soil in fertility. This sister plot, too, has been unmanured for nearly sixty years, but it is sown with wheat every other year only, lying fallow for the intermediate years. From this are reaped every other year crops yielding sixteen or seventeen bushels of grain to the acre, and a very fair quantity of straw. The recovery of the ground is always marked in comparison with the neighbour plot, which, however, produces a third or so more in two crops than the other in one.

We shall get a striking picture of the fecundity of the ground if we compare these unmanured acres at Rothamsted, which may represent the thinnest and cheapest form of cultivation imaginable, with one of the French or Dutch market gardens, which may represent the most intensive and expensive form of cultivation practised commercially. At Rothamsted the natural soil, which was a rather poor soil even at the beginning of Sir John Lawes's experiment, is left to do its own work. In the French garden the soil is manufactured altogether. In the first case one very poor crop is reaped, in the other five or even six rich crops can be grown off the same soil. Between these two extremes come, at all sorts of intervals, the ordinary field and market garden methods of cultivation, of which some trust to what may be called the natural fertility of the land, some to the manufacturing principle.

A Wonderful Idea that is Revolutionising Methods of Cultivation

Prince Kropotkin, who is one of the chief pioneers of this intensive cultivation, expressed, in a remarkable little book, called "Fields, Factories, and Workshops," his belief that some day we should most of us come to regard the land as a sort of manufactory. In a number of very remarkable records taken from gardens in France and from that wonderful "Valley of Glass" in the island of Guernsey, he showed that an acre of land, if treated on just the same principle as machinery in a factory, could, in the best circumstances, produce no less than £1000 worth of food. Of course, this sum is only made possible by very high prices. The gardens so treated could produce fruit and vegetables out of season, and for these the highest price can be obtained. But the mere weight of stuff produced strikes one as at least as wonderful as the value of it. The French gardens grow ton after ton of food. Harvests, so to speak, succeed one another at a few weeks' interval, since many are sown simultaneously. As soon as the radishes are pulled in March, the date when in many cases the single field crop for the year is being sown, the lettuces in the same frame are already large, and the carrots and cauliflower, which are to make the two succeeding crops, are already considerable plants.

How the British Isles Could Maintain their Entire Population

The following is a list of some, but not by any means all, the crops grown in one year on a plot of about 2¾ acres: "More than 20,000 lb. of carrots; more than 20,000 lb. of onions, radishes, and other vegetables sold by weight: 6000 heads of cabbage; 3000 lb. of cauliflower; 5000 baskets of tomatoes; 5000 dozen of choice fruits, and 154,000 heads of salad. In short, a total of 250,000 lb. of vegetables." It is scarcely to be wondered at that with such examples before him, gathered from many parts of the world, Prince Kropotkin should prophesy a future in which the earth, so far from being used up, should double and treble its produce.

"The resources of science," he says, "both in enlarging the circle of our production and in new discoveries, are inexhaustible,

THE CANADIAN FARMER'S WEALTH OF AGES

The richness of the soil of Canada is due to the fact that for centuries vegetation has lived and died there, each plant taking food from the sun and air and rain, and storing it up in the soil, and the Canadian farmers have thus the wealth of ages to draw upon; and as one layer becomes exhausted, all they have to do is to plough lower. This photograph shows a farm on the Canadian Pacific Railway.

and each new branch of activity calls into existence more and more new branches, which steadily increase the power of man over the forces of nature. If we take all into consideration; if we realise the progress made of late in the gardening culture, and the tendency towards spreading its methods to the open field; if we watch the cultural experiments which are being made now—experiments to-day and realities to-morrow—and ponder over the resources kept in store by science, we are bound to say that it is utterly impossible to foresee at the present moment the limits as to the maximum number of human beings who could draw their means of subsistence from a given area of land, or as to what a variety of produce they could advantageously grow in any latitude. Each day widens former limits, and opens new and wide horizons. All we can say now is that 600 persons could easily live on a square mile: and that, with cultured methods already used on a large scale, 1000 human beings—not idlers—living on 1000 acres could easily, without any kind of overwork, obtain from that area a luxurious vegetable and animal food, as well as the flax, wool, silk, and hides necessary for their clothing."

The Great Work of Water in the Building Up of Crops

But we need not go to a French or Dutch garden to find an example of the astonishing weight of material that the soil, if properly treated, may produce. What a future of energy the growing of the crop suggests! An acre of mangels will actually, lose in what may be called the outbreathing of the plants, over 1000 tons of water. The weight of the mangels may in special cases come to eighty or ninety tons, without the great and abundant leaves. It has been calculated that a crop not half this size consumes up to ten inches of rain. When one sees the little rough dry seeds committed to what may seem most uncongenial soil, and later walks through the forest of leaves concealing roots that may weigh half a hundredweight, and considers the elaborate manufacturing processes that have been automatically performed, one is astounded at the response of the soil to the requests of men.

But the more one looks into the process, the more one is struck by the huge part played by water. In the eastern parts of England, which are the driest, the crop of mangels wastes or breathes out nearly half the rain that falls on its area. When we look into the methods of cultivation we shall see that nearly all of them, from hoeing to ploughing and rolling, are concerned with the conservation and use of the water in the soil. All the greater marvels of production are due to the use of great quantities of water.

The effect of water on the hay crop of the meadows, as contrasted with the upper pastures, is apparent to everyone. Indeed, it has often struck students that the soil of England ought, so to speak, to be much less fertile than it is. And in one sense this is so. If we had fewer rains and less mists the soil would lose fertility in proportion to this deficiency. But many areas regarded as scarcely worth tilling are very rich.

The Remarkable Results to be Obtained by Mixing Clay and Peat

Clay soils, for example, especially the very fine-grained and close clays which look most barren, are composed of every sort of mineral wealth. In this respect they are not less rich and even more inexhaustible than the famous black soils of Russia. The principal reason why they are let for cheap rents, and often produce poor results, is that they are so difficult to handle, to plough, to break up into a seed-bed, to aerate and drain. Supposing for a moment that loads of the peaty soils on which nothing useful to man is grown were ploughed into those heavy clay which break farmers' hearts and left to decay, we should have a soil as rich as any in the world. The minerals in the clay are almost inexhaustible, and the peat would supply the decayed vegetable matters in which they are deficient.

Of course, the soil is in one respect not so rich as it appears, for plants can only take up food while it is in solution, and many of the constituents of the soil seem to be insoluble in water. That can hardly be called wealth which can never be used; and apparently rich soil may serve as little else than an anchoring ground for roots.

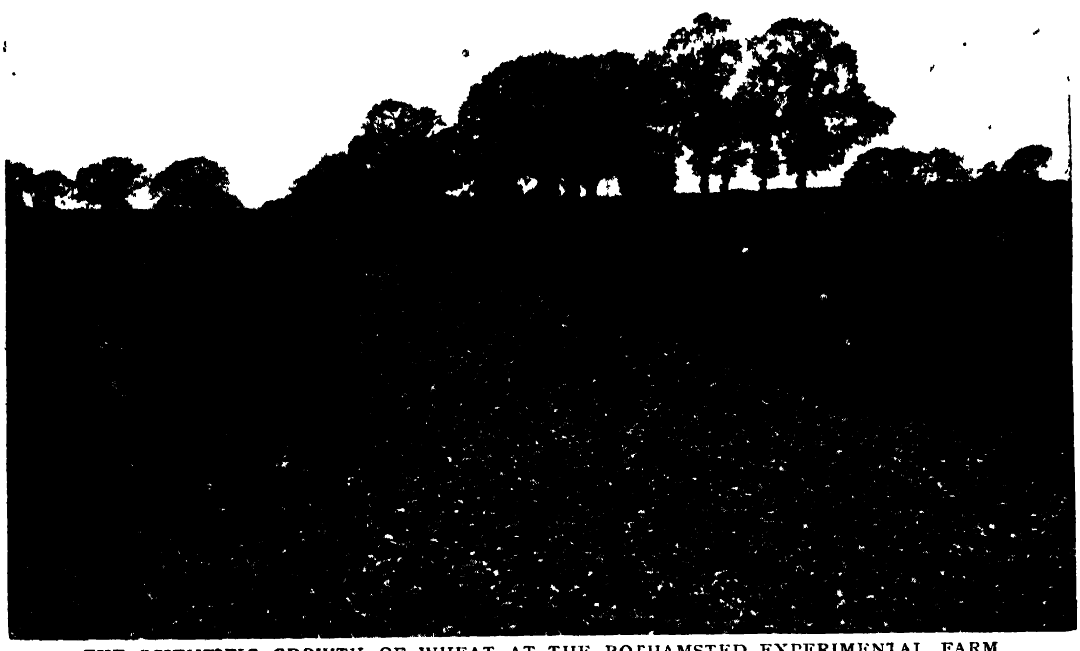
Canada, the Great Wheat Country that is Living on Its Capital

England is without any virgin soils, and yet she produces some of the heaviest crops in the world. Russia, which on the whole is rather a barren country, has one enormous stretch—some 150,000,000 acres of soil so rich that great wheat crops have been grown on it without manure for just about as long as on the Rothamsted plot. This black soil goes down in places some twelve to fourteen feet, and its richness comes from the immense amount of decayed vegetables which has made it. It is black for the same reason that the soil in the older French gardens is black. It has been manufactured by nature, not by man—out of the

manure of decayed vegetation; and this loam is so full of food and of bacteria that many generations of crops will make little impression on it. Something akin to this black soil is found in the English Fens, which were drained for us by the Dutch, and which now bear immensely heavy crops of corn. But they are very shallow compared with the Russian, and a great part of their natural richness is withdrawn, though they will always be rich.

The alluvial soils, which are rich in rather a different way, are sometimes of immense depth. There are regions of Canada, where the alluvial deposits, composed throughout of silt of a nature to make any cultivator's mouth water, are piled to a depth of thirty feet and more. However, the great prairies of virgin land in North-Western Canada are not so deep in soil as this, and some are rapidly becoming exhausted in the sense that they will not much longer bear continuous wheat without manure. At present the common system is to take two or three seasons of wheat, then to leave the land fallow, then to return to wheat, but the farmers who do this know well that they are using up capital, and that the people who follow them will have to cultivate scientifically, and perhaps keep stock. In this way a good deal of soil is being exhausted, in the usual sense of the word. But all that exhaustion means is that in the future more trouble will have to be taken.

Perhaps the most astonishing general example of the restoration of soil to more than its natural fertility is to be seen in the Channel Islands. Thanks very largely to cattle, and yet more to the climate and the energy of the people, a land which used to produce little, and is naturally rather barren than fertile, now produces vast stores of food, and instead of losing wealth is gaining it. If we were to reach a period when food was becoming very dear we could make almost any land fertile, as they have done in North Germany and in Belgium. It is only because there is still so much virgin soil in the world that land which needs more care and trouble and expense is neglected. But every year, as people increase, and the virgin soils are used up, this duty of using the soil, which is always able to give out stores of life, is being more and more appreciated. Never in the history of the world has any country depended so little on its own soil as England, and yet nowhere in the world has such valuable scientific work been done in showing how great and wonderful are the possibilities of the soil.



THE SCIENTIFIC GROWTH OF WHEAT AT THE ROTHAMSTED EXPERIMENTAL FARM

The chief point of the agricultural experiments at Rothamsted is the long-continued use of the same manurial agents. By gradually exhausting the soil of particular constituents, the continuity brings to light the function of any kind of plant-food in a way that is not possible in a few years, because of the large reserves of all plant-foods contained in ordinary soil. The two plots shown in this picture receive the same treatment alternately, one receiving minerals and the other ammonium salts every other year. It has been found that the minerals yield less than half as much as the nitrogenous manure, the influence of which seems to end with the year of its use.

A GROUP OF POLAR BEARS AT HOME IN THE HEART OF EUROPE

Polar bears, whose natural home is amid the ice of the North Polar regions, live for many years in a temperate climate, and here we see how Herr Hagenbeck solves the problem of furnishing them with a home in the heart of civilisation, at Stellingen Park, Hamburg. Polar bears rarely rear cubs in captivity.

THE BEAR AND HIS COUSINS

The Principal Species of Bears and Their Close Allies—the Pandas, Raccoons, and Kinkajou

THE MONARCH OF THE FROZEN WORLD

NATURALISTS have no difficulty in agreeing that bears constitute a group to themselves, but there are no water-tight compartments into which we can rigidly divide animal life. To attempt such a classification is to contradict Nature.

Nature is never brusque; she makes no abrupt boundaries. She does not arbitrarily create a type without experimenting further with variants. She is adaptive rather than inventive, as Lamarck has said. We often have to dig deep to fathom the secret of the means by which she has arrived at the results before us. If we could conceive of Nature as a personal entity of human attributes, we should imagine her laughing at the pitfalls into which some of her devices lure us.

We have a case in point in the bears, a family of carnivorous animals, widely distributed, but distinct and apart from all other animal creation. So we used to say. Little more than forty years ago, an animal known as the great, or short-tailed, panda was discovered, and men added it to the ursine family, calling it the particoloured bear, which is the name that any naturalist, ignorant of its anatomical structure, would apply on first seeing it to-day. But, bear-like though it be, it is no more a bear than a wolf-hound is a wolf. Related to the bears it is, but it belongs, not to the bear family, but to the raccoon family.

It is a link which had been missing from our living chain of animals, and it serves to connect the raccoon family with the bears. When the destinies of the dog family were being shaped, another line of carnivorous animals was at the same time being slowly evolved. They descended from the same ancestry as the dog, but they became, on the one hand, bears; on the other, pandas and raccoons. And now that the mystery is solved, we divide all these animals into only two families, of which the bears form the first. The bears and raccoons preserve for us the method of locomotion common to the ancestors of themselves and of the dog family.

All the bears and raccoons are plantigrade—that is to say, they walk flat-footed. So did their remote mammalian ancestors. The dogs have greatly modified this method—they have specialised means of locomotion. But the bears have, to an equal extent, advanced upon their primitive model in the matter of dentition. The teeth of the dog are fashioned for the eating of flesh, and though wolves and jackals, and some other members of the tribe, eke out with a vegetarian diet, it is from necessity rather than choice. The teeth of the bear, however, are adapted practically to every form of diet. In fact, vegetable feeders are the rule rather than the exception among bears. Even the Polar eats weeds from the sea, and browses during the short Arctic summer upon such vegetable growths as his habitat affords; while berries, grass, and the foliage of trees are as acceptable to the savage grisly bear as a mess of honey or the carcase of deer or horse.

In bulk and physical strength the gorilla has become the greatest of the Primates, and the bear occupies a corresponding position among the Carnivora. By making the best of the plantigrade action with which he began his career, the bear has become one of the most formidable and widely distributed of all animals. He shambles along in ungainly fashion, but he has pace, and he can accommodate himself to practically every condition possible to animal life, excluding the realm of the birds and the haunts of the deep sea fishes. He can climb a mountain as easily as he can scramble up a tree ; he develops a hairy

growth upon the soles of his colossal paws to prevent his slipping on the ice; he can swim so well that one has been seen making its way at sea undistressed forty miles from land or ice; torrid climate or Arctic does not prove a barrier. He can eat anything—fish, flesh, or vegetable. He has nothing like so big a brain as the anthropoid ape, but such brain as he possesses has enabled him to adapt himself to circumstances better than any other animal, the dogs alone excepted. The gorilla has gone too far, yet not far enough, and needs millions of years to perfect himself, but the bear, with his primitive gait, has really done better, in all but mental potentialities, than the lords of the Primates.

But there has been a fault somewhere in his career. The most promising of the bears emulated many other early animals; developed immense size and power, completely out-distancing all their dog-like relatives. Carnivorous mammals reached their maximum development in the colossal cave bear with which palæolithic man in England was brought in contact.

Why did the cave bears die while smaller bears of the same period survived? Probably strength and ferocity were its only assets. Great bulk and mighty force are not always accompanied by the agility necessary for the maintenence of life in such a form, or the prehistoric monsters of the slime would not have vanished, leaving nothing but their bones. This huge bear, which could kill nearly any other terrestrial animal, and drag its body to its cavern, there to gorge upon its remains, must have been almost the most dreaded of man's foes. The puny biped fought it with hatchets and spears of flint. It can hardly be that man alone was responsible for its extermination, though the brain that guided the hand in the shaping of a flint was a miracle of contriving mechanism in such an age. The paramount cause must have been the natural operation of the law which determines the issue of the struggle for existence; the smaller, more active, more adaptable bears probably starved out the more powerful but less agile and intelligent giants of the family.

Until the tale of the Alaskan bear was told, we of the present age had always considered the Polar and the grisly the head of the family. The Polar is big and formidable enough to satisfy the man who wanders northward, and with good reason, as we shall presently see. It is a wonderful testimony to the adaptability of the bear family that almost the finest members of the family should be found in the coldest, most inhospitable regions of the earth. The Polar bear inhabits the whole of the Arctic Ocean, remaining near the edge of the ice cap, coming south in the winter, and retreating north in the summer, always keeping as near as possible to the sea margin. Here, amid the everlasting ice, it has attained magnificent proportions, a length of nearly nine feet and a weight of from 600 lbs. to 700 lb. being not uncommon in the adult. Its food consists of fish, the flesh of seals and the walrus, the carcases of dead whales, and any animal or vegetable food—carrion or garbage—that it can secure. During the winter the female hibernates, snugly ensconced beneath the snow, while the males remain upon the prowl throughout the winter, having with them the cubs of both sexes. Throughout the long winter the female lies beneath the snow, and there brings forth her young. She must have within her system a sufficient reserve not only to support her own life during this long period, but to afford milk to her cubs. These generally number two. They are born naked, blind, and helpless, unable even to wriggle a few inches to their dam's side should they be disturbed.

A RISING HOPE OF THE ARCTIC

The Polar bear cub is born naked and helpless, and is suckled by a dam which has spent the winter fasting in the snow.

Photo by W. P. Dai

In the close confinement of their snowy lair there is not much danger of their being lost in this way, of course. There would be a serious thinning out of Polar bears if the conditions of the nursing home were suddenly altered, for the Polar bear is a stupid mother when removed from her natural surroundings. Barbara, the splendid great she-bear at the London Zoological Gardens,

FROM THE ARTIC SNOWS TO LONDON—SIXTY POLAR BEARS THAT ENTERTAINED A LONDON AUDIENCE

It was long supposed that the Polar bear ferocious and intractable could not be tamed. Here, however, are over sixty Polar bears not tamed but trained to take part in a Christmas spectacle in London. The bear in the foreground displays the hairy pads which enable the animal to run on ice and turn swiftly without slipping

has on four occasions presented her lord with cubs, but on each occasion she has let them die—not through lack of affection, but from sheer stupidity, carrying them naked and blind and tender out into the freezing air of the open space beyond her den. Polar bear cubs flourish in a snowy crib in the coldest land in the world, but they die of pneumonia when their dams are at liberty to carry them with foolish pride out into the open in the temperate London winter.

Polar bear dams are really as unwise in conditions such as these, as some human mothers who have, in the twentieth century, to be compelled by law to sweep, wash, and ventilate their rooms, and to abstain from

feeding their babies on pork chops and gin. In a state of freedom the Polar bear has not the temptation to expose her offspring until they are furred, active, and strong. When she does emerge with her cubs, she is the most faithful of mothers. Nothing could exceed the pathos of an oft-quoted example of this fidelity cited by Captain Phipps. A dam and her two cubs approached an exploring frigate which was frozen in the ice, encouraged by lumps of flesh thrown to them by the sailors on board. These the old bear fetched away singly, laying every lump before her cubs as she brought it, and, dividing it, gave each cub its share, reserving only a small portion for herself. The sailors shot the cubs and wounded their dam. "It would have drawn tears of pity from any but unfeeling minds to have marked the affectionate concern expressed by this poor beast in the last moments of her expiring young. Though she was herself dreadfully wounded, she carried the lump of flesh she had fetched away, as she had done others before, tore it in pieces, and laid it before them; and when she saw that they refused to eat, she laid her paws first upon one and then upon the other, and endeavoured to raise them up. All this time it was pitiful to hear her moan.

A BROWN BEAR AT LARGE

A brown bear enjoying the freedom of Yellowstone Park, U.S.A. Bears of this species abounded in England a thousand years ago

"When she found she could not stir them she went off, and, when she had got to some distance, looked back and moaned; and, that not availing her to entice them away, she returned and began to lick their wounds. She went off a second time as before; and, having crawled a few paces, looked again behind her, and for some time stood moaning, but the cubs still not rising to follow her, she returned to them again, and with signs of inexpressible fondness went round, pawing them and moaning. Finding at last that they were cold and lifeless, she raised her head towards the ship, and uttered a growl of despair, which the murderers returned with a volley of musket-balls. She fell between her cubs, and died licking their wounds."

To restore the balance it is necessary to remember that the Polar bear is not always the innocent victim, as in this case. A Polar bear which, after a fair chase, will run down, kill, and eat a man, will creep noiselessly upon another as he sits on the ice, strike him down with its paws, then draw off to see if he is dead.

This fearlessness of the bear in the presence of man is an interesting feature, for the same temerity does not mark the attitude of all the ursine family. Nor does the same attitude characterise all Arctic and sub-Arctic animals. There is something in the scent of a bear which is terrifying to nearly all other animals save man, and there is a terror for all other animals in the scent of man. This has been very interestingly shown by Mr. Charles Sheldon, who has travelled lately in the Upper Yukon. On one occasion he killed a grisly she-bear far up among the mountain peaks. The bear's cub, which was quite tiny, faced the hunter without the least sign of alarm, and he determined, if possible, to capture it alive. When he got to within six feet, the cub, for the first time, caught the scent of man; and, after sniffing several times in acute terror, it raced away at such speed as to render pursuit useless. On another occasion a cow moose and her calf allowed the hunter to get within fifty feet of them, and to take a photograph without their moving. Yet the moment he moved round so as to give them his "wind," they "jumped as if receiving an electric shock,"

and fled like the wind. But it is not so with Polar bears, or Sir Savile Crossley and a friend would not recently have been able to shoot fifty-seven of these animals in Spitzbergen in the course of but five weeks.

The monarch of the frozen world displays a good deal of cunning in stalking its prey, and considerable intelligence in its choice of hunting grounds. And there is something to be said for the intelligence of a huge beast which has learned safely to cross rotten ice. The Polar bear, faced with such a problem, stretches himself flat at full length, with all four limbs widely outstretched, and, by thrusting with his hind feet or gripping with the hairy soles of his fore-paws, can safely overpass a stretch of bad ice which would engulf him if he tried to walk across it. And cannot something be said for the reasoning power of the brute which, seeing for the first time a trap set by man, avoids it ? Nansen's men baited one near the Fram, and watched a bear approach. It badly wanted the lure of tempting blubber, but it went all round the trap, examined its framework, dubiously shook its head, walked a second time round it, followed the wire upon which the trap depended, made another general survey, gave its head another and final shake of suspicion and disapproval, then stalked determinedly away. It is in the highest degree unlikely that that bear had ever before seen a trap.

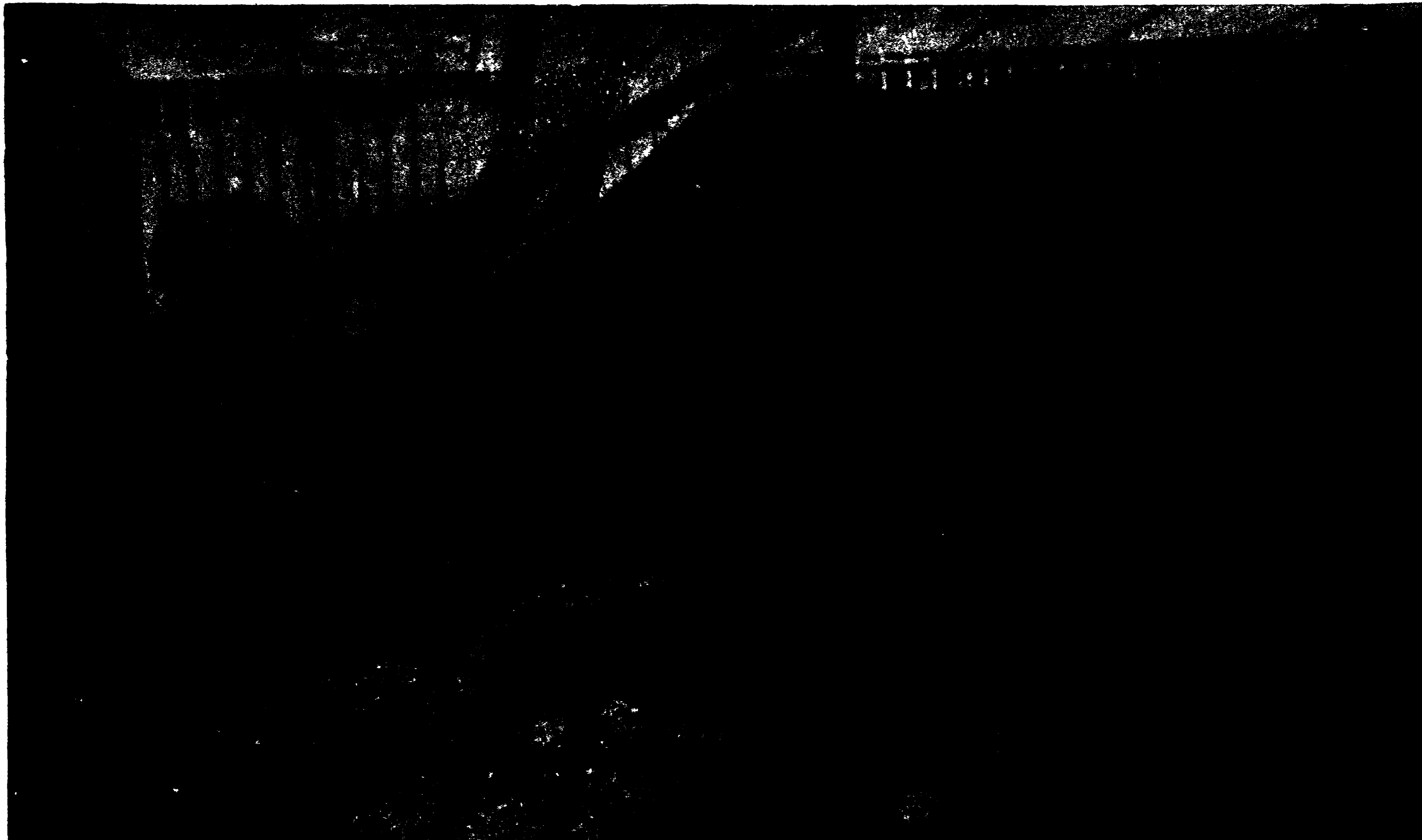
The brown bear was one of the owners of ancient Britain. The Romans found it here upon their coming, and exported the animal to Rome for sport in the circus. But the bears outlasted the Roman conquerors here. Down to the time of Edward the Confessor the town of Norwich had yearly to furnish one bear to the King. One authority has it that bears may have existed wild in Scotland until shortly after the arrival of William the Conqueror in England. The general body of evidence goes, however, to show that bears disappeared from England about the beginning of the ninth century, having vanished from Ireland a century earlier. Although he has been exterminated in the United Kingdom, the brown bear still maintains himself, except in populous areas, practically throughout Europe, and the whole of Asia northwards of the Himalayas, including Siam and Japan. Formerly the species ranged from Great Britain right away to far Kamchatka.

THE GREAT BROWN BEARS OF ALASKA, THE BIGGEST BEARS NOW IN EXISTENCE

The brown bears of Alaska have deposed the Polar bears, which were long regarded as the giants of the family. Polar bears have been known to measure nine feet long, but their Alaskan cousins are found occasionally to reach a length of ten feet, not counting the tail.

It is perhaps natural that an animal having so extensive a range should show considerable local variations, both as regards size and coloration. The Syrian bear, the snow or isabelline bear of the Himalayas, and various brown bears of America have, with others, all been put forth at from time to time as different species. The highest opinion, however, groups them all in one species. The brown bear is more often herbivorous than not, feeding upon bulbous plants, upon grasses, upon fruit, nuts, berries, and cultivated crops; but it will kill and eat animals, from mice to men. It should be added that, as a rule,

THE GRISLY BEAR THAT CAN CARRY OFF A VICTIM WEIGHING HALF A TON



The grisly bear has enormously developed its claws, and, however exaggerated have been the tales of its savagery and size, it has veritably proved a terrible devastator of the flocks and herds in the neighbourhood of the Sierra Nevada. This captive animal was photographed by Mr. Bushnell.

the brown bear will, if possible, avoid an encounter with man. It suffices for the bear to get a man's scent; it will bolt. If pressed by hunger, however, or if cornered, then it will fight—and kill and eat a man as readily as will a man-eating lion or tiger.

During the winter the brown bear hibernates. It seeks the shelter of tree or cave; it scrapes a hole beneath a fallen tree; it may even enlarge burrows begun by other animals. When it goes to rest it is fat and sleek. Instinct teaches the animal when its condition is such as to warrant its going to its winter bed. After a bad season, in which food has been scarce, it will not retire at the normal times, but eagerly continue searching for food which shall enable it to lay up within its body the store of fat necessary for the maintenance of its life when all its functions, save respiration and circulation, are suspended.

When it emerges from its hiding-place in the spring, the female bear brings a couple of cubs in her train; she has supported herself and them, since their birth, upon the store accumulated within her own organism in the preceding autumn. All the bears fresh from hibernating are lean and hungry. They feed voraciously on a vegetarian diet, or they may raid herds of cattle or droves of horses, if these be handy and other forms of food scarce.

The brown bear of Kamchatka lives for a time entirely upon the salmon that crowd the river waters. Entering the water, it faces down the stream, and stands perfectly still. The fish probably regard its massive limbs as the trunks of trees and fearlessly approach. Then like lightning the forepaw is raised, and a swift blow is delivered; the fish is transfixed by the terrible claws, and the bear leaves the river to eat as much of the fish as appeals to him. No matter what the size of his prey, he, like the otter, always quits the water to make his meal on land, and during the season the banks of the river are found strewn with the remains of fish which he has left.

THE RACCOON, A DISTANT ALLY OF THE BEAR

Although so unlike a bear, the raccoon is connected, through the great panda, with the bears, descending from a common ancestry.

The great brown bear of Alaska differs little in habits from its European and Asian relative, though it is larger. Specimens from Kadiak Island, Alaska, are said to reach a length of ten feet from the snout to the root of the tail. On the Sitka coast region of Alaska we have a smaller, though still very large local race; and the Yakutat and Kidder's bear of the mainland are huge animals. All these Alaskan bears are reported to be less fierce than the grisly, though far exceeding the latter in size. They will kill human beings, but they are really omnivorous, and eat fish, flesh, fruit, roots, grass, herbage, kelp, and berries. They do not scorn the mice and ground squirrel or any other animal that they can catch.

The famous grisly has enormously developed his claws, and this has caused him to sacrifice his tree-climbing powers. Whatever may have been its dimensions in the past, the grisly does not, on the average, exceed much over 6½ feet to-day. In view of this, it is interesting to remember that we have brown bears in Europe measuring 8 feet, and that the largest of the Himalayan bears run to from 7 feet to 7½ feet. But the grisly is American, hence the tale of his size and manners has lost nothing in the telling. But, in truth, *Ursus horribilis*, as formerly known in the high ranges of the Sierra Nevada, was a terrible enough beast, said to have weighed as much as 1800 lb., and certainly from 1200 to 1400 lb. In that region these bears were poisoned upon a large scale, for it was impossible to keep flocks for them. The grisly, though mixing his diet with great freedom, is probably the most carnivorous of the whole family, and has been known to kill a bull bison with a single blow upon the neck with one of his mighty paws, and to carry away a male wapiti weighing nearly 1000 lb.

Smaller than the grisly, but quite as fierce when at close quarters, the American black bear has at least three interesting variants. One is the so-called cinnamon

bear, which is merely a pale-coloured race; the rare glacier bear; and a third known as *Ursus kermodei*. The latter is regarded as merely an albinistic example of the true black bear. Formerly enjoying an immensely wide range all over the northern half of the American continent, this black bear is now necessarily finding its territory more and more restricted.

The Powerful Grisly Bear whose Savagery has Become Fabulous

This is inevitable, for, as new land becomes settled, the bear must go; no farm stock is safe from its ravages, even quite large animals being killed and eaten by it. Possessed of immense power, it kills with tremendous blows from its forepaws, while its teeth are said to crush the bones of an ox.

That it is a courageous fighter is well known, but a specific example of its courage is afforded by a scene which Mr. Ernest Thompson Seton witnessed in the great Yellowstone Park, where wild animals roam at will in a state of semi-freedom. A black she-bear and her cub were feeding upon a garbage heap in the park, whence she had driven a number of other bears. Towards evening a large grisly approached, to the manifest alarm and discontent of the cub. She turned to her little one and gave a gruff signal, whereat the cub scuttled up a tree, while she went towards the grisly. She stood as high as she could, and set all her bristles on end, then, growling and chopping her teeth, she faced him. As he drew near she charged at him with a great roar, and gave him a terrific blow on the ear. The larger bear, taken by surprise, recovered himself, then gave her a cuff which knocked her over. Nothing daunted, she jumped up and closed with him. They clung together, rolling over and over, biting and pounding, then separated and drew apart. The grisly did not wish to continue the fight, and moved in the direction of the heap, but as he did so the black bear, though wounded, attacked him again.

The Black Bear that Haunts the Forests of the Himalayas

This time the grisly was on his guard, and he dealt her one blow which knocked her backwards, crash on to an upturned pine-root. He followed her up, but she, desiring no more fighting, dodged him round and round the root, until he tired and sat up, enabling her to bolt to the tree in which her cub was secure, and to scramble rapidly up into the branches to safety.

The Himalayas have their black bear, readily identified by the inverted crescent of white on its chest. It is, for the most part, a forest-haunting animal, ranging from about the eastern portion of Persia, through Baluchistan into Afghanistan and Sind, thence through the forest-clad portions of the Himalayas to Assam, and so on to Burma. The species is found also in the islands of Hainan and Formosa, and in Tibet. The spectacled bear, so called from the presence of tawny rings round the eyes, is a small black species inhabiting the slopes of the Andes, and appearing in Chile, Bolivia, and Peru. The bruang, the bear of Malay, is believed to be a near ally of the spectacled species. It is smaller and more agile than the other members of the family, and possesses an extraordinarily mobile tongue, the result, no doubt, of long ages of partly insectivorous diet.

Our survey of the bears closes with the curious cumbrous Indian sloth bear. Measuring from 4 to 5½ ft., this bear differs from all the rest of the family in possessing two fewer teeth than the normal number, in the long snout, and the baggy, pendulous lower lip, and in its exceptionally long, shaggy, and coarse hair.

The Sloth Bear which Ravages the Ant-hills of India

It is a slow, ungainly beast, sustaining itself mainly on fruits, flowers, honey, and insects, though not disdaining at times a meal of carrion, or a delicacy in the form of a dead beast's bones, which should have been the perquisite of the hyena. It has a great fondness for white ants, or termites, and has obviously specialised in their capture. Its immensely powerful claws enable it to tear open the hills of these insects, when it reveals an extraordinary power of suction and of propelling air from its mouth. Having gained access to the lower galleries of an ant-hill, it blows with great violence, scattering the dust and crumbled particles of the nest; then, with equal vigour, sucks out the inhabitants of the comb with such forcible inhalations that the larvæ from great depths under the soil are drawn forth.

Passing now to the pandas, we have first the great, or short-tailed, panda, which, as already noted, is superficially so bear-like a beast as to have been long classed with the ursine family. Resembling the sloth bear, it has only forty, instead of forty-two teeth, like the rest of the bears. Structurally it closely approximates to the true pandas, and the balance of evidence goes to class it

with the raccoon family. Its fur, which is long and close, is for the most part white, but the eyes are surrounded by black rings, the limbs are black furred, while the shoulders are marked by a transverse bar of the same hue. In general outline, the short-tailed panda would pass as a very small brown bear of aberrant coloration. Its home is in Tibet and North-West China, and its diet, so far as is known, consists solely of roots and the young shoots of bamboos.

No bear can retract its claws, but the true panda, which is popularly known as the cat-bear, has the power of half withdrawing them. The panda has the true plantigrade walk of the bear, and the soles of its feet are covered with hair. In size that of a big, bushy-tailed cat, the panda is a superb tree-climber, but closely resembling the great panda in certain anatomical features, it is, like that animal, mainly herbivorous, but in captivity eats bread-and-milk and eggs and small birds. It hisses like a cat, growls like a bear, laps, at times, like a dog, but commonly immerses its muzzle and drinks by suction, after the manner of a bear. The panda is a native of Asia, but had its home in England in days when we had a sub-tropical climate and abundant forests.

The Raccoon that Saturates its Food with Water Before Eating

The raccoons themselves are mainly carnivorous, living upon mice, young birds, fresh-water tortoises, fresh-water mussels, and insects, with an addition of nuts, fruit, and corn. Occasionally, however, a raid upon a poultry-run shows in which direction the animals' preference lies. There is one species, the crab-eating raccoon, whose diet is sufficiently indicated by its name. This is a semi-aquatic mammal, but, like the other raccoons, makes its homes in the trees. The raccoons are tree-climbers because they find no other place secure. Their food is sought chiefly upon the ground, but they make their homes among the branches; they hibernate there in the colder part of their range, and there their young are born.

They have the bear-like gait, and possess the same number of teeth as the sloth bear. One peculiarity of the raccoon is that it immerses its food in water before eating it, and the instinct of one at the Zoo induced it to behave in the same way with some kittens put into its cage for company. The feat satisfied the raccoon, but it killed the kittens.

Three or four other animals come into the raccoon family—the cacomistle, a dweller in well-watered woods, and an enemy to poultry; the bassaricyon, an allied genus peculiar to Costa Rica, Panama, and Ecuador; the kinkajou, and the coati. The kinkajou, as the only member of the family which has developed a prehensile tail, is perhaps more completely at home in the trees than any of the others.

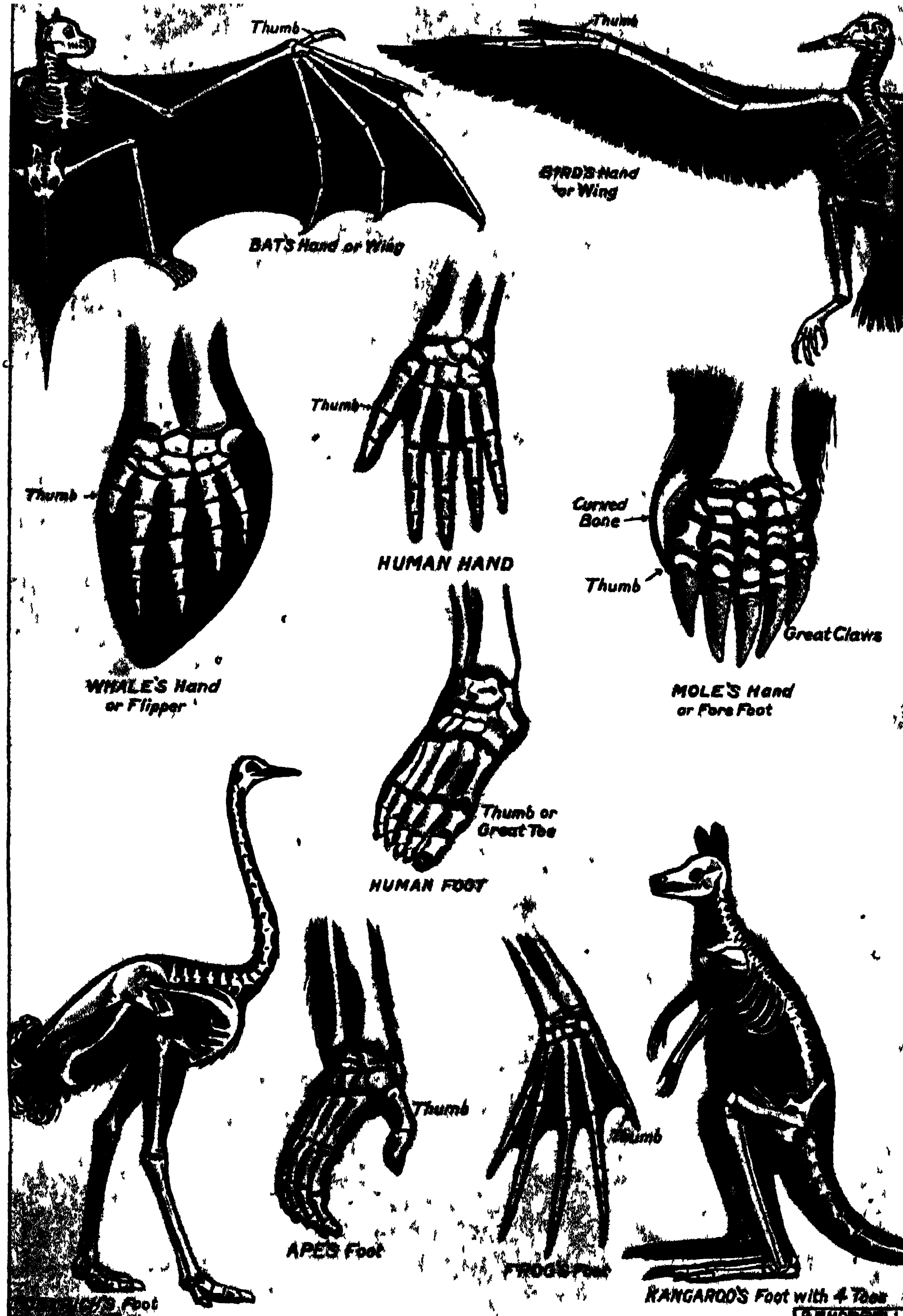
The Co-operative Hunters in the Forests of Central America

The natives regard it as a type of monkey, and it has a lemur-like appearance. But the paws are paws, not hands, armed with powerful curved claws, not nails, and the dentition is unmistakably that of the raccoon family. Equalling a full-grown cat in size, the kinkajou eats small mammals and birds, fruit, and honey. In moving through the trees kinkajous, which collect in troops, take considerable leaps from bough to bough. A strange development for a distant relative of the Polar bear!

Two species of coatis are known, one common to Mexico and Central America, the other inhabiting South America, from Surinam to Paraguay. With its short and sturdy limbs, its plantigrade gait, and its excessively long snout, the coati has for its German name a description signifying "the proboscis bear." These animals are good climbers, and chase lizards among the trees. The reptiles thus pursued drop to the ground, only to find a second detachment of the animals hunting below in obvious agreement with those in the branches overhead. The coati can be easily tamed, and makes a docile and interesting pet. All the members of the raccoon family, except the aberrant pandas, are natives of the American continent, the home of the majority of the bears.

The Close Kinship Existing Between the Bear and the Dog

The contrast between these distant allies, the Alaskan giant and the pigmy coati, is a startling one, but not more so than the difference between a typical elephant and the degenerate elephants no bigger than Shetland ponies which once had their home in Europe; and not more startling than the contrast between a Polar bear and a hairless Mexican dog of to-day. Bears and dogs are kin, bears and the prehensile-tailed kinkajou are kin, more distantly, but clearly connected through the pandas. We place them in different families to-day, of course, but there is no doubt as to the common origin of all these animals.



On this page are a few examples showing how man is ill adapted for flying, burrowing, climbing, swimming, running, and leaping, in which things the bat, bird, mole, whale, frog, ape, ostrich, and kangaroo outclass him Yet man, with his mind, has become a creator, and has made his body the simple, all-capable, adaptable, supple, obedient, and limitless instrument of his creative mind

MAN MADE FOR THE UNIVERSE

The Human Instrument by which the Mind of Man Works Out Its Creative Purpose in the World

THE AMAZING MECHANISM OF A HUMAN BEING

We repeat that man is body and mind, or body and *psyche* for mind is really an inadequate word– or "body, soul, and spirit," in the language of the past. We must remind ourselves of this, because when we consider the body in detail, as is done by the sciences of anatomy and physiology, we are constantly tempted to suppose this is all.

Only when our survey is finished, and we realise that it has scarcely been begun, and that all the ultimate questions have been left unanswered, do we realise that, however deeply we have probed with the knife and peered with the microscope, we have only seen one aspect of man, and there remains the psychical side, which escapes our grasp. It is probably true to say that no one attempts to study anatomy and physiology without passing into a stage of materialism, in consequence of the compelling and absorbing nature of these studies and their convincing character, so far as they go.

Some never pass further, but those who turn from the dissecting-room and the laboratory to living men and women, doing, daring, fearing, thinking, creating, inevitably pass through materialism as a child passes through chicken-pox, and are for ever immune thereafter. Here we are to study the whole man, and must devote a just share of our time to what is beyond touch or vision, but is much more obviously real than anything that can be touched or seen. As we study, we shall find ourselves constantly asking a question which men have asked from the beginning of time, and which may always remain unanswered: What is the relation between mind and body? The answer may never be forthcoming, but it is immeasurably better to have asked the question than never to have faced it at all.

Here, then, we deal with man's body, and at the first moment we see that our subject may be divided into two parts. On the one hand, we may study the "form", structure, and construction" of the body, in general and in detail; and, on the other, we may study its working. Anatomy—literally cutting-up—is the study of structure, and physiology is the study of function. These go hand in hand, and can only be studied intelligently together.

We cannot study the function of the heart without first identifying the heart; and our anatomical description of the heart, its walls and the flaps inside them, cannot even be intelligible unless we know its function, and understand that the walls squeeze a fluid within them, and the flaps are valves to secure the right working of this living pump. Always, therefore, anatomy and physiology are studied together; and in most parts of the world the professional teachers of physiology take over and deal with the whole of what is called minute anatomy, that is, the anatomy of the tissues which is conducted with the microscope, but is just as much—or more—anatomy as is the jointing of the skeleton. This minute anatomy is one of the great sciences of the future, for it carries us much nearer the very home and temple of life than any naked-eye anatomy can do, though evidently we require first to learn what the unaided eye can teach, and then go in detail, with every possible aid to vision, over each organ and tissue of the body.

The first requirement is to consider the body of man as a whole, taking not a bird's-eye view—though what the bird sees is the most important part—but an ordinary human view of a fellow-being, or of ourselves, as we really are under our clothes, before a looking-glass.

Even at a glance much is to be learnt. Clearly *the body of man is an animal.* To say, as we often do in cynic or would-be

scientific vein, that man is an animal is simply to confound things that are obviously different—which is exactly the opposite of any scientific procedure. But to say that the body of man is an animal is strictly accurate, and says neither more nor less than the truth. The writer wishes that this simple phrase could be accepted in this connection, and perhaps some day it may be. If we are not offended at realising that our bodies are made of matter, as chairs and rocks are, we need not be offended at realising that this matter is put together and built up on a particular plan which is so definite and peculiar, and yet so familiar, that we cannot think of dog or cat, or horse or mouse, or elephant or monkey—nay, even of bird or fish or frog—without seeing that, whether we like it or not, the body of man is an animal, and an animal of a definite type, belonging to a definite class, together with certain other animals, and to the exclusion of the rest.

A word as to this. Animals either have backbones or have none. Man has a backbone, and his body is therefore a vertebrate, or back-boned animal, and is almost immeasurably nearer the fish than, say, the bee. All vertebrates, including man, classify themselves readily into fishes, amphibians, reptiles, birds, and mammals.

The Great Difficulty of Fitting Man into His Place

It is as clear that man's body is a mammal as that it is a vertebrate. He is a member of the mammalian class, agreeing with the essential characteristics of that class; its members bring forth their young alive—as we say, though of course a bird's egg is alive—and the mothers suckle their young by means of special organs which are known as mammæ, and from which the name of the order is derived. Also, these creatures are provided with hair, as distinguished from the scales of the fish or the feathers of the bird.

But though the mammalian character of man's body is clear, and though its vertebrate character is not less so, we do find some difficulty when we compare him with his asserted allies. Some vertebrates have no limbs, as fishes and snakes. But most have limbs, and the number is customarily four, we notice. Never is it more—the sea-serpent, a vertebrate with more than two pairs of limbs, is unthinkable to the student of animal anatomy. It is true that in birds the number may momentarily puzzle us, but we agree that it is still four, though as the bird hops or walks we only notice two. We may call the bird a biped; and then we see that man is a biped, too, and thus, on this reckoning, seems to be nearer a bird than a mammal, though we have positively asserted that he is far nearer to the mouse or the elephant than to any bird. The evident answer, as we know, is that man has the typical four limbs of the vertebrate, and that these four limbs are mammalian, endowed with hair, not feathers, and that it is only the peculiarity of man's upright posture which appears to ally him more nearly with the bird than with the four-footed "beasts of the field."

The Vertebrate with Its Skeleton Inside and the Invertebrate with Its Skeleton Outside

We may note, also, that other mammals have gone their own peculiar way, as man has, and that the whale appears to answer very imperfectly to the idea of a mammal. But man and the whale are far more closely related than man and bird, or man and fish.

If we look at the body of almost any animal, we find that it evidently has hard parts and soft parts. Such a simple animal as an amœba has no hard parts, but it is so small that it needs no supporting framework or skeleton. But a lobster or an oyster, or a fish or a man—these have hard parts as well as soft; and at once we see an enormous difference between man and all other vertebrates on the one hand, and all invertebrates on the other. The invertebrate wears its skeleton outside its body, and the vertebrate has its skeleton inside its body. Hard inside, soft outside, is the vertebrate rule, and to this rule man conforms. It contrasts him, say, with the lobster, no less than the possession of a backbone; and it allies him, obviously, with the whale and the fish, against the "shell-fish," so called, which are not fishes at all.

Thus we see the body of man, a four-limbed mammalian vertebrate, having an internal skeleton, supporting soft tissues, and covered with skin which bears not scales or feathers, but hairs.

The Vertebrate that has Developed a Skull and Lost a Tail

Like other vertebrate bodies, his has a long diameter or axis, coinciding with the backbone, and at one extremity of this long axis we find a typical head, while at the other we note that a visible tail is conspicuous by its absence. The trunk is the central and axial part of the body, as it is also the oldest historically, and the head is a special development from its end of the trunk, even though we may no longer agree with Goethe and other precursors of evolution, who thought that the skull was modified

from the vertebræ at that end of the backbone. This backbone is situated, of course, near the back of the body, though not outside it, like the back-armour of an invertebrate. On the opposite aspect of the body we notice evidence, in both sexes, of the presence of the typical glands which give their name to the mammalian order.

From near the head end of the trunk there springs one pair of limbs, and from near the tail end there springs the second pair. These, with their attachments to the trunk, constitute a series of appendages to the axial part of the body, so that anatomists are in the habit of speaking of the *axial* and *appendicular* parts of the skeleton respectively. If, now, we compare these parts of man's body with the features of the bodies of the lower animals, we find an extraordinary measure of correspondence, going far deeper than the surface. There is no choice but to give the same names to the biceps of a man or of a gibbon, to the shoulder-blade of a man or a mouse.

Man's Perfection the Result of his Extraordinary Imperfections

Thinking of ourselves, in our typical erect attitude, we speak of front and back. The anatomist, however, who is bound to be a comparative anatomist, studying the different types of animal body simultaneously, is often compelled, of necessity, to think of man in the posture of the lower animals, and thus he uses the word "ventral," from the Latin for the stomach, as in ventriloquy, or stomach-speech, and the word, "dorsal," from the Latin "dorsum," meaning back, to indicate the two aspects of the body, so that the same words can be used to compare upright man and horizontal mouse, when the details of anatomy are under consideration.

But at this point we begin to find that the body of man is strange and unprecedented when compared with its nearest allies. Each of these allies, no doubt, differs from the others; the elephant and the bat and the whale are each strange and unprecedented enough. Man is so in a totally different way. Each of them is made for a particular environment and kind of life; man appears to be made *for none in particular, and therefore for all.* These simple words express one of the chief facts of science, and he knows nothing of the science of man who ever forgets them.

Consider, for instance, locomotion. This is a cardinal matter, for the body of man, like all other animals, requires to move in search of its food, whereas plants, whose food is almost everywhere, do not require to move. It follows that, whatever animal we study, we find it prepared for locomotion, *of one kind or another*. What kind, will depend not on chance or caprice, but on the inner nature of the creature, and its needs of diet, offence and defence, and shelter.

The Adaptation of an Animal's Limbs to Its Special Functions

Thus, every sort of animal tends to become a specialist in one kind of locomotion or other. The bird takes to the air, and finds itself soon compelled to make all manner of sacrifices so as to be as good a flier as possible. The sloth takes to trees, and soon obeys the same necessity, like the fish or whale in the sea, and the horse on land, or the hippopotamus—the river-horse, as its name means—in the river.

Now, every specialisation necessarily involves sacrifice. Every animal that adapts itself to one environment, by so much unadapts itself to others. Birds may swim and dive, and fish may fly, but these are special feats, and the bird must return to the surface or die, and the fish must return to the depths or die. You cannot sacrifice fingers to make wings and fly, and then expect to play the piano, or even grub for worms, with your wings. The key that exactly fits one lock fails to fit another; and just like key and lock, are species and environment. It must be a skeleton key, or a master-key, that can contrive to fit all or almost all locks; and strange it will look beside all those which are specialised for one lock alone.

Now, if we look at the body of man from the point of view of locomotion, we are puzzled. Seriously, if we came from Mars, and were faced with man, and knew nothing of him, though we did know all other species, we should not know where to place him.

The Physical Powers of Many Animals that are Superior to those of Man

We should place him, indeed, among the mammalia, and so forth, but where to place him, literally, we should not know. Is his body meant to walk or run, climb, swim, fly, or burrow? We have only to glance at bird, fish, mole, monkey, antelope, to answer such a question, but man's case is not so easy. Certainly, he was not made to fly, never did fly, and never will fly—it being remembered that we are speaking of his body. His mind may be up to anything, but we are not now talking of that. Nor is it made for burrowing, for instead of claws he has the most inadequate nails, which are useless

for the purpose. Certainly he can swim, and in the most favourable possible conditions, accompanied by a tug, he may even swim the Channel.

But this is a rare and extraordinary feat, just because the body of man was certainly not made for swimming. What was so obvious as regards flying that we did not even need to point it out, is scarcely less so as regards swimming. Man's limbs are evidently unsuited for the purpose; and we have only to watch a swimmer who has equipped feet and hands with plates to realise what it means for whale or fish or web-footed bird to have large flat surfaces for purposes of swimming.

The Triumph of Man's Nervous System Over His Body

Man is somewhat web-footed and web-fingered, as we have all observed, perhaps, in comparing the length of the fingers seen from in front and seen from behind, but he was not made for swimming; and his feats in the water, whether as a swimmer or as a boat-builder, are like his feats in the air—they stand more to the credit of his nervous system and his mind than to the credit of his body.

Then perhaps man was meant to climb. His heavy, all-important head, which is such a problem for the swimmer, does not matter in the mechanics of climbing. Further, man's ancestors were arboreal, and his teeth are well adapted for eating fruit and nuts and leaves. But again he disappoints us. His body is far heavier, in proportion to his limb-strength, and especially his arm-strength, than a monkey's. His hands can grasp exceedingly well, none better, but his feet — what a falling-off was there, we may say in two senses! For they cannot be trusted at all, and may at any time cause his destruction, yet they are descended from feet which grasp as well as hands. Man's feet are very degenerate feet, it seems. The great toe cannot be opposed to the other toes, as the thumb can be opposed to the fingers; in losing the opposable great toe of his ancestors man lost for ever his tree-climbing powers.

The Value of the Tail as a Fifth Hand for a Climbing Animal

Every boy who has been taught to climb a rope, and grasp it with his knees and feet, knows by personal experience how wide is the contrast of climbing utility between feet and hands, but the ape and the monkey know no such difference.

Man's climbing is thus what his swimming is—a feat, and has to be learnt and directed carefully by the nervous system against serious difficulties, always. And if we have any doubt of the strange falling off of man's body in this matter of climbing, we may remember the expert decision about the monkey's tail. Not only do many monkeys use their tails as a fifth hand—and one cannot have too many hands for climbing—but even those which do not actually grasp with their tails use them for purposes of balancing, when they walk along a branch. The tail touches the branch behind, sometimes on one side and sometimes on the other, partly helping the balance mechanically, and partly doing so by sending hints of the body's position up to the balancing centre in the nervous system. Man has the skeleton, and somewhat more, of a tail of sorts; but it is of no use to him in climbing, or for any other purpose. Even the kangaroo, which is somewhat erect, after man's fashion, gets locomotive advantage from its tail, and is man's superior in that respect.

Man's Great Inferiority in Two Important Factors

There remain nothing but walking and running, crawling being out of the question for a creature with hands and feet like man, except as a feat in emergency, like climbing and swimming. Doubtless man walks and runs very well—for him; and we may argue that other suggestions were not worth making. But in point of fact man's ordinary mode of locomotion, though his best, is by no means perfect. In any kind of locomotion, we chiefly consider two things—speed and endurance.

These are the two factors that matter for life; and we find animals that live by the one, and those that live by the other, some having much of both. We recognise these two points in our sports, with their sprints and their long-distance events. Man is instantly outclassed by scores and hundreds of animal competitors in either kind of trial. His sprinter cannot catch a dog or a cat or a rat, because these animals have four legs to his two. When man withdrew his fore-limbs from locomotion he withdrew from any chance of competition as walker or runner at any distance.

But his plight in the only form of locomotion which he can boast at all is much worse than any racing can show. His feet, pitiably inadequate for climbing, are only one degree better for walking. Their nakedness is deplorable. No claws, retractile or fixed, no velvet pads, no hoof, no thick, dense, resistant development of skin,

such as the elephant has; nothing but a naked, soft-skinned sole, which any little thorn or jagged stone may disable. We wear boots and shoes; our primitive brothers wear what they can make, binding cloth or rushes or something round their feet; and wooden clogs are hard to beat.

But with nothing—what a quandary! To be barefoot has always been the sign of poverty and misery—adopted therefore by barefoot friars, but even they must have sandals. Do we not see what a remarkable fact this is—that practically nowhere can man walk along barefoot, and yet his body is adapted for nothing else?

The Veins of Man that are Unsuited to His Erect Attitude

With feet which cannot climb, or walk unprotected, man need not be surprised to find that the erect attitude, which leaves his inadequate feet unaided by his hands, is by no means suited to the rest of his body. The walls of veins are thin, and apt to stretch. Therefore veins have valves in them, to prevent the blood from surging backwards and to limit the weight of blood that must be supported inside any length of vein. These valves are found exquisitely placed, say, in cat or dog, so that the risk of injury to the vein shall be as small, and the advantage to the onward circulation of the blood shall be as great, as possible. Man also has valves in his veins, and could not do without them.

But, behold, they are not where they would be most useful. They are distributed throughout the veins and limbs in just such fashion as would be most useful for a four-footed creature, walking on ground or bough, with its backbone horizontal. But man walks erect, with a long, straight line up and down from hip to ankle, and he pays the price. He cannot walk or run or stand for long without his feet swelling, because the circulation of the fluids upwards from the feet, against the pull of the earth, and with the valves of the veins misplaced, is arduous, and soon becomes imperfect.

Man the Paragon and Man the Paradox of Animals

Doctors know quite well how readily the ankles become puffy when health is impaired, and how, when the stocking is taken off at bedtime, the foot is marked by the pattern. They know, too, how the veins become stretched and varicose, and how the health of the skin is impaired in consequence. Now, these and many other ailments of the veins and the circulation in the lower limbs, and also many ailments of the feet, depend upon the fact which we have already proved: that man is very imperfectly adapted even to what is evidently the easiest mode of locomotion—walking about on the surface of the land.

Such being the anatomical facts, man is found everywhere, as no other creature is, and wherever man is found he is lord of the earth. The condition of this pre-eminence is in his mind, and his body serves it by being Jack of all trades, and master of none. He has not specialised it to fly, walk, swim, burrow, climb, but it is sufficient instrument for making flying-machines and railways, and boats for the surface and the depths, for digging mines and building skyscrapers. No other creature has gone along this road—the one open road of life—and thus man's body, compared with that of any other creature, is a sort of nondescript, the least specialised, because it is the most adaptable. Shakespeare called him the paragon of animals; he is no less the paradox of animals.

This, that, or the other animal has been made a key to fit and turn the lock of a particular environment. Man the creator has a mind which makes him, at will, a key to fit and turn almost any environment, and even to make new environments such as Nature knew nothing of before his day.

The Marvellous Instrument by which We See the World

This principle—that he is to be capable of anything, and that therefore his body must not be mechanically specialised for any one thing—applies to the whole of his life. We have here illustrated it from the case of locomotion, because that is fundamental for any animal, and because the illustration is so clear. But it applies everywhere; and one of the best signs about modern anatomy and physiology is that we are beginning to look at the structure and the function of the body in the light of our knowledge regarding the kind of life that man leads, and the kind of method to which he trusts in his competition with other forms of life. Much of the unwise criticism passed by anatomists upon the body, much of the bewilderment as to this feature or that, or as to the loss of a feature which seems so useful—say, an opposable great toe—disappears when we learn to look at the body of man in this new light.

For instance, if we turn from locomotion to sensation, no less important, we may well begin by looking at the eye. When we do so, we find that this organ, marvellous

though it be, is imperfect in many ways. Forty years or so ago, the great Helmholtz said that if the eye were sent him by an optical instrument maker, he would return it as most unsatisfactory in structure and design. Huxley saw deeper when he pointed out that the eye is imperfect as a telescope, imperfect as a microscope, imperfect as a camera obscura—but it is something of all these. Admirable is the highly specialised eye of the dragon-fly, with its tens of thousands of facets; admirable, also, the long-distance eye of the hawk, but what compared with the eye of man, naturally focussed on infinity, but capable of use for hours at a time at the shortest distances, and then ready to gaze at the stars again? It is not only something of all the instruments we have named, but it is something of a spectroscope as well, and has no rival in the living world for discernment of colour-differences. The optician can construct a spectroscope which analyses light better, but will he also contrive to give it the properties of a microscope, a telescope, a photographic plate, and a cinematograph into the bargain?

The Sense of Smell that has Given Way to the Sense of Hearing and Vision

We might consider the other organs of sense, and make the same observations, but it is almost more to the point to notice the nose alone, and mark the conspicuous inferiority of smell in man.

The organ is there, with its appropriate features, as found in other animals, and with nothing more to remark as out of the way than we find elsewhere in man's body. But when we observe it more closely, we find it positively degenerate Man cannot be bothered with it. Such a sense, highly specialised for use along with taste, at short distances especially, was all very well for creatures which work at short distances, and, in another use, for creatures which live by hunting prey which they must scent. Man, the ubiquitous, omnivorous, creative, will not burden the precious interior of his skull with the large nervous centres necessary for the full development of such a sense. He needs more room for senses like vision and hearing, which his mind can employ in speech, the all-adaptable; and so the nose may degenerate.

Hence, the general facts of man's body, when we have placed it in the animal kingdom, and have failed to place it on the earth—for it will go everywhere—are largely negative. Apart from its erect attitude, it is an unremarkable body, mechanically and superficially inefficient. Endow man's body with any brain less than man's, and he would become extinct at once. Give him the brain of the highest ape, and set that the task of maintaining life with the body of man—it would be impossible. The higher apes have no tails, it is true, and already thus foreshadow that loss of old-established physical characteristics which is the mark of man's body.

The Efficiency of Man's Brain that Makes Up for His Physical Deficiency

Apes, however, are fairly covered with hair, which is an immense protection to the skin from all manner of risks—dirt, light, scratches, and many more. Man has not even that.

As if in bravado, or to show plainly what his principles are, he has even divested his body of its coat of hair, and prefers to clothe it with what his brains enable him to take from other animals, or what they make from the products of the vegetable world. He is a creature whose first home was tropical or semi-tropical, observe, but set out to conquer the earth, from the Equator to the Poles, and began his journey to colder climates by shedding his coat of hair. This paradoxical fact is highly typical of man's body, in its deepest as well as its superficial aspects.

When we come to study his instincts and intelligence we shall find how deep this principle has gone. Other creatures have specific instincts, adapted to their environment, and to no other, just as they have specific structures, for single purposes.

The Ever-growing Intelligence that has Supplemented Human Instinct

Man, for his part, has shed these specific, rigid, within their domain perfect, but uneducable instincts, just as he has shed claws and hair, and threatens even to shed his teeth. Such instincts would get in his way, just as fine birds' wings for flying, at the cost of his fingers, would lower instead of raising him. In the domain of mind we find that the rigid, limited instincts of his ancestors, perfect for their purpose, worse than useless in any new situation, have yielded in the main to something called intelligence, which knows nothing "by nature," requires to learn, and takes a very long time about it. But intelligence knows no limits; it can employ man's no longer rigid but plastic instincts, it is capable of adapting itself to all possible conditions of existence, and of adapting the outside world to itself.

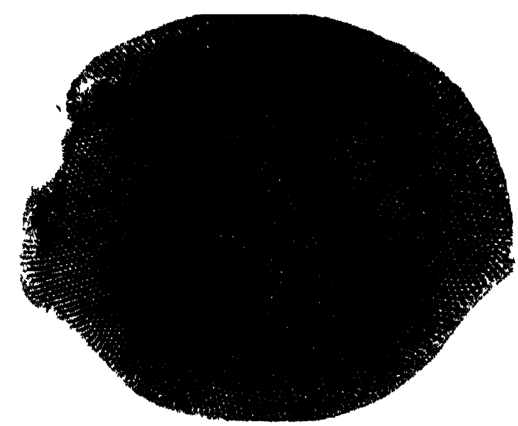
Thus we see that this unique being, made of body and not-body, is consistent throughout In other aspects of his being he is at first sight particularly undistinguished; and that is why he can distinguish himself in every possible sphere, and beat every animal at its own game.

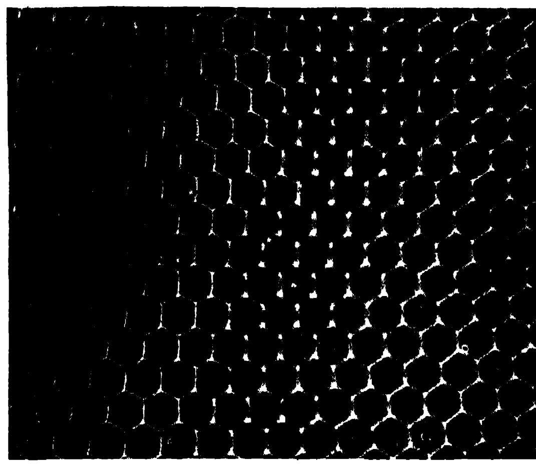
Again, how much more clearly is the paradox pointed when we look at the body of man in its infantile state! If it is open to criticism when mature, it is simply ridiculous, if not pathetically inept, when immature. The human baby is the most helpless of living things, and will be lord of the earth. It is helpless in body, and all but helpless in instinct. Its intelligence shows not a trace of its coming; and while its body is not adapted for anything but the erect attitude, it is yet many months short of being adapted even for that. But this naked, helpless, inept object, ridiculous from the mechanical point of view, since its balance is so defective, and no less ridiculous from the point of view of instinct, or of muscle, or of sensation, is so exactly because it is preparing for a universal conquest, and must not allow itself to be led into any cul-de-sac at the start.

Every other living creature is in such a cul-de-sac. Brains may grow somewhat larger, bones stronger, leaves greener, but in every case all has been staked upon one limited possibility of environment. Man alone has travelled the open road, and, while he has sacrificed nothing vital, has lost and continues to lose whatever is not worth his while on this endless journey. Other creatures find a niche in the world, fit themselves, and rest and are thankful. But it is the splendid attribute of man that he never is, but always to be, blest. No niche in the world is good enough for him. He proposes to remake the world, and does so at this hour—severs continents, creates new chemical compounds for his protection from microbes, builds cities, and so forth.

The body of man is an animal, but it belongs to a creator, and it is the body of a creator, who accepts it not as a finished or final product, but as an instrument of his creative purpose. The instrument of the great artist must be simple, a brush, a pencil, a chisel, not complicated like the machine that makes a pin, because the great artist does not know what he is to make until he tries, and there is no end to the variety and scope of his work. Therefore he requires a simple instrument, which is adaptable to any purpose—a pencil which can write an addition sum or an epic, a chisel which can make a mantelpiece or a Madonna, an alphabet and a musical scale which can make all language and all music.

Just so is man's body, and more so will it become, the simple, all-capable, adaptable, supple, obedient, limitless instrument of the creative artist, who looks upon the earth and upon himself, finds neither all and wholly good, and is now steadily, very slowly, but very surely achieving with this strange new-old instrument of his, which we call the body of man, the purpose of the mind of man, which is to take the world without and the world within, and remould it nearer to the heart's desire.





TWO REMARKABLE PHOTOGRAPHS OF A BEETLE'S EYE

Such an eye as this is in many ways, perhaps, more wonderful than the human eye; it is highly specialised and consists in reality of thousands of separate eyes. The human eye cannot claim such high specialisation as this of the beetle, but it has properties infinitely more wonderful. The human eye is imperfect as a telescope, imperfect as a microscope, imperfect as a camera obscura, but it is something of all these. The left photograph shows the whole eye of a beetle; the right shows a small part more highly magnified.

"A FAVOURITE CUSTOM"—FROM THE PAINTING BY SIR LAURENCE ALMA-TADEMA, R.A.
The baths of the Romans were probably the largest and most luxuriant in the world's history, some of them having a capacity for three thousand bathers. A perpetual stream of water was poured into the capacious basins through the wide mouths of lions of silver. "To such a pitch of luxury have we reached," says Seneca, "that we are dissatisfied if we do not tread on gems in our baths."

THE LAW OF THE BATH

One of the Imperative Decrees of Health and How Its Demand should be Obeyed

THE VIRTUES OF HOT AND COLD WATER

SINCE all life is lived in water, as we know, and since it is certain that the body is always losing water, a new supply is always required, especially as our power of storing water is very small, and disastrous consequences follow when we store more than a very limited quantity. Our needs in this respect are shared with all forms of life, but we further resemble other high forms, such as trees, in that we no longer take water in at all points, but only by a special channel. The tree is rained upon or we may be drenched to the skin, but neither of us takes in one drop of water in consequence.

First of all, therefore, we must study the laws of health in regard to external water—water which never enters the body at all, but may affect it. We have only to remember the mysterious company of ailments conveniently, and ignorantly, called "rheumatism," and their connection with damp states of the air or of one's clothes, to see that water outside the body may affect it not only obviously but also subtly, no less than water inside it.

In all the air we breathe there is water-vapour, as one of its normal gaseous constituents, and this we inspire with the rest. But as we always give out more, in each breath, than we took in, evidently the body receives no water from the inspired air. It does not follow that the water in the air is of no consequence. On the contrary, its quantity affects us deeply. Strictly speaking, what matters is not the quantity of water in the air, but the proportion of it, in comparison with what the air can possibly hold. The warmer the air is, the more water it can hold; and a warm air may thus contain far more water than a cold air could. But what matters to us is that the cold air, perhaps, is filled with water, or saturated, whereas the warm air, though holding far more, has not exhausted its capacity. We therefore require to introduce the idea of a relative humidity of the air to express its proportion of actual to possible moisture at any given temperature.

This question of relative humidity is of unceasing importance to the meteorologist, who is constantly concerned with the instruments that register it, and finds its consequences everywhere. But we have lately learnt that it is of no less importance in matters of health. The body must continuously lose water if it is to live; the process is exactly and entirely as essential as the need for the continuous intake of water. But while the task is largely undertaken by skin and breath, and is easy and rapid when the relative humidity of the air is low, of course it is hampered when the relative humidity is high.

Within the last few months experiments have been carefully repeated, and were described at the British Association meeting at Portsmouth in 1911, which prove conclusively, by exact observation on man, what has hitherto been only presumed. We now know that one of the chief causes of fatigue, headache, depression, lack of appetite and subsequent anæmia, following exposure to confined air, is the fact that such air soon gets loaded up with moisture, and then retards our loss of it. The subject is so important, and will require to play such a part in future reforms of housing and ventilation, that we must return to it.

Meanwhile, we note that, while no water from without really enters the body by the lungs, any more than by the skin—both being organs for getting rid of water—it matters immensely that we live in an atmosphere which contains water; and our health cannot long be maintained in any atmosphere which contains such a proportion of actual to possible moisture that our getting rid of water is too much retarded.

If one hundredth part of the hygienic attention paid to the quantity of carbonic acid in air had been paid to its relative humidity, we should all be much wiser in our practice by now.

But when we think of water outside the body, we naturally turn to washing, and there we may continue, though carefully remembering that the body has an inside as well as an outside, and that water is needed inside as well as outside for the elementary purpose of cleanliness. If one had to choose between the two, one would have to take internal washing, for that is necessary to life, and external washing is not.

The Matchless Waterproof Material which Admits Water One Way Only

The skin is absolutely and at all points waterproof. One could not otherwise survive a bath. The appearance of water-logged skin, water-logged from within, is characteristic and tragic. Not only need we not fear such results from exposure of the skin to water, but we must not hope to absorb either water, or any salts or tonics, or drugs or foods, dissolved in it, by means of the skin. Sea baths or medicated baths may or may not be useful, but we are definitely to abandon the notion that any of the contents of the water enters the body. Only by means of an electric current, specially applied, can we persuade medicaments or foods dissolved in water to enter the body. It follows that any possible results of the use of such special waters must follow from their action upon the skin and its nerves, from without. The skin is not less perfectly waterproof in the inward direction than it is perfectly permeable to water in the outward direction. It is thus, of course, the ideal waterproof, never to be rivalled by any invention of man, for, however light and well contrived our clothing may be, it can never hope to equal the admirable skin, which lets no water in and lets all water duly out.

The Right Kind of Exercise that a Morning Bath Affords

We may confidently say that modern knowledge of the body and of disease has not robbed water of its place. Our business in these pages is to get at the root of this matter, not least because the process may help us to ascertain how far one may practise such means of health at home, and how far it is essential to have a flowing purse, and betake oneself to, say, the hot mud establishments of some Austrian spa. If we all remembered that nothing dissolved in water enters the body through the skin, we should be better prepared to spend our means wisely when in search of health.

To begin with, it is good to wash because it is good to take exercise. This is a sensible kind of exercise, just sufficiently interesting to the purposeful mind. It involves much variety of movement. In the course of washing, the skin is rubbed and massaged mechanically, quite apart from the action of the water upon it. This exercise is reasonable in the morning, for it is not too much strain upon the nervous system, which takes many hours really to wake up and be at its best; and also it is a tonic, and helps the nervous system to bestir itself. But if the action upon the skin is really to be tonic it must be induced in the right way. We want the skin to have its circulation improved, but by no means to become congested; we want its nerves to be stimulated, but not to be made irritable and over-sensitive. If we use too hot water, or do not take care to neutralise its effects, the result will be to cause the blood-vessels in the skin to relax, the nerves to send messages of slackness to the brain, and to deprive the vital organs of blood by diverting so much of it through the channels of the skin.

The Right Kind of Feeling to Have on Leaving the Bath

What exactly will have the good effect and what the bad in any given case, only the person in question can decide. But the upshot of the washing, looked at from this point of view, must be to leave the skin cool, braced, perhaps glowing, but *also* cool, in the delicious fashion so familiar to everyone who has taken a bath of the right kind. That is the vital reaction; and if one does not get it, a change must be made until one does. But to take a bath of any kind, at the end of which one is warm, perspiring, sleepy, and idle, is utterly wrong in every case, however clean it may have made one, except only when sleep is needed and when bed is promptly sought.

Healthy people should not require to aim at this warm, lax condition of the skin, because it should come of itself, neither too much nor too little, when we grow normally sleepy. Such kinds of bathing are to be looked upon as medical, though nothing but ordinary water be used, and are to be regarded by healthy people as medicine is. And just so soon as the sleep is restored, and the undue flow of blood to the brain is no longer a bad habit at bedtime, but has been broken by the bath, just so soon should this kind of bath be modified—as the

doctor modifies his dosing with a hypnotic as soon as the patient can sleep without it.

If the hot bath is taken in the morning it must be so taken that one does not leave the room hot and perspiring. We must run in cold water or have a shower, or not have the bath so hot to start with, or not stay in so long, but somehow we must contrive to leave the room keener for the day than when we entered it. The brain-worker who gets his letters in bed, longs to answer them, grudges the time for his bath, and after it finds himself genially philosophic and in no hurry, has had a bath of the wrong kind. The external cleanliness may be very satisfactory, but if one has so affected the body as, in the long run, to hamper and retard one's internal washing, then one is really the dirtier and the worse in the long run. The pity is that, in this matter, as in so many others, personal, social, and political, we act on the great maxim of folly that what is not seen is not dirt.

In general, the hot bath is better at night than in the morning, but even at night it must not be excessive. It has further advantages at night, in that it is cleaner than a cold bath. It should always be brief, the hotter the briefer, and on the whole it is not to be named as a means of health compared with a bath which is fairly warm, just warm enough, but not nearly hot.

The Hot Bath for Cleanliness and the Cold Bath for Tonic

Hot water has enormous advantages for washing with if it be properly used. It is the rule that the body fats and oils are just between liquid and solid at the temperature of the body. Hot water liquefies those which have passed through the skin, and those oils also which we get from the smuts of city air. The stimulation of the nerves by heat is good if it be brief, and especially if it be followed by cold. One of the recognised methods of encouraging the breathing of a new-born baby which is not doing well enough in this respect is to apply hot and cold water alternately to the skin. For other people hot first and then cold is the right sequence. If one were to bathe twice a day, the hot bath should be the cleaning bath at night, and the cold bath should be the tonic bath in the morning.

Hot water should be cautiously used for the skin of the face, which is very thin, and the nerves of which are very numerous and sensitive. Many women use very hot water frequently for the face, because of the perfect cleanliness which it alone makes possible, but they should beware of dilating the blood-vessels of the skin beyond the point at which they quickly and entirely return to their former size. Anyone with a tendency to a red face, or a red nose in particular, should avoid using any but lukewarm water—and cold water, of course—for the face, and should beware of hot baths, with their obvious tendency to increase the quantity of blood in the skin.

The Limits of the Virtues of the Cold Morning Bath

The cold bath in the morning is a standing English tradition, and has been praised and practised far beyond its unquestionable merits. The writer's risk in all such cases is that the hasty reader will now conclude that the cold bath is here decried. It is not decried, but its virtues are simply being defined. They have limits, like the virtues of other things. One has seen an elderly lady, long past seventy, who took a cold bath every morning, summer and winter, as she had done all her life, and who often required the entire morning to recover from its effects. It may have been admirable for her once, but it was most certainly not so when she was found with teeth chattering and fingers blue an hour later.

It may be said that such cases are very rare; but there are countless cases, at the other end of life, where young children are brought up on the hardening system—which too often ends prematurely as a stiffening system—without reason and observation from day to day being brought into play. The test of the cold bath is in its consequences. The elderly and the very young stand cold badly, and react to it imperfectly—which is another way of saying the same thing. The strong and those in general who are not at the extremes of life are caused by the cold to produce more heat than ever, reacting to it as a highly bred horse to the flick of a whip, or as an orator to a great occasion.

The Exposure to Cold that Produces More Heat and Energy

It can be experimentally shown that exposure to cold, which necessarily deprives the body of heat very rapidly, soon thereafter causes the production of more heat and more energy, which are duly supplied for, in their turn, by a marked increase in the appetite and speed of digestion. This is simply one of the countless cases where the body is induced to call up its reserves, by being somewhat attacked. Mere vaccination induces so much resistance that one defies smallpox, though the vaccination merely called upon

one to defy vaccinia or cowpox. And here exposure to a little cold induces a reaction which would enable one, if necessary, to withstand far more. Similarly, a person with anæmia may be bled, in order to induce the body to form as much blood as it should—far more than merely to compensate for the blood removed. This is one of the ultimate principles of our lives, in health and disease of body and of mind; and to learn it once and for all is a long way towards hygienic wisdom.

How Long Should We Stay in a Cold Bath?

Now it takes only a very short time for the body to react to cold. This must be so, for the attack of cold is immediate; we begin to be chilled instantly, and should soon succumb if the compensatory process did not begin at once, and then it will continue long after the immediate necessity has passed, just like the immunity after an attack of scarlet fever. Since the reaction is so quick, it follows that the exposure need not be long. How long it should be will depend upon the individual. For each of us there is a degree of exposure which will produce the most reaction, and degrees beyond that which will produce less and less, until at last the reaction fails.

The problem for each of us is to find the right point, and not to exceed it. How long am I to stay in my cold bath? the foolish reader may ask, but the writer is not so foolish as to tell him. You are to stay in your bath just so long as suffices to produce the most pleasant, warm-cold glow thereafter, and the best vigour for the rest of the day. Generally speaking, those who employ cold water at all for these purposes tend to overdo it. They very excusably think that, if half a minute does them good, five minutes will do them ten times as much good, just as people think also about quantity of exercise.

The Vital Reaction of the Body that Takes Place After Bathing

They are quite wrong; the reactions of the body are not mechanical or mathematical, but vital; and they cannot be measured on such simple reckonings as these. Indeed, the proposition has been laid down that the value of a cold bath is in inverse proportion to its length; and though that is, of course, not strictly accurate, and ignores the particular behaviour of the individual case, it is so nearly true that it may be usefully remembered. The vigorous and mature may forget it, but directly we have to deal with the elderly or with the young we must remember it. If we do not, we had better avoid any cold bathing for them at all; but if we remember that it is good for them, but the less they have the better, then we may usefully employ this magnificent natural tonic at any age whatever.

Though we may be inclined to suppose that when a man has fever he is least able to endure exposure to cold, and should be tightly wrapped up, according to the appalling medical practice of not many years ago, the fact is that fever is just the condition in which exposure to cold can be borne, and may often save the patient's life, by lowering his temperature in the safest possible way. Cold sponging, cold bathing, the "cold pack," and other forms of employing ice itself, are the recognised and best methods of reducing many kinds of fever. Obviously it is one thing to lower a normal temperature to five degrees below normal, and another to lower to the normal a temperature which was five degrees above it. The former is a departure from health, the latter a return to it. But many years must pass before the public appreciates the fact, and ceases to fear cold water internally and externally in fever, not to mention cool air, or ceases to pile the blankets on people who are already too hot.

The Danger of the Sponge, and the Care with which it should be Used

The massage and friction of the skin which naturally go with most forms of bathing have already been praised. The stimulation of the nerves of the skin is very useful, alike to the skin itself and to the brain. Further, the friction is itself cleansing, quite apart from either soap or water, for it removes the old and inevitably dirty layers of skin which lie nearest the surface. The value of the nailbrush not only for the nails but for the whole hands has been proved long ago by surgeons, who know that this employment of it is an essential preliminary to true cleansing of the hands. The use of rough gloves in the bath, and of "loofahs" and similar rough substitutes for sponges, is to be recommended.

Surgeons do not now use sponges, for they know that these are incapable of real cleansing or disinfection. They use instead swabs, which are only employed once. Doubtless we may freely continue to use sponges in ordinary life, but we should be scrupulous about their cleanliness, for sponges are with difficulty prevented from being dirty things. So apt are they for

the harbourage and conveyance of infection that any sponge permitted in a house at all should be the property of only one person, and used by no one else. The domestic sponge probably plays a considerable part in the conveyance of tuberculosis from one member of a household to another, when they are on familiar terms, not to mention maladies like a common cold and influenza, boils and acne, and similar infectious conditions of the skin.

The Harm that May Come from too Vigorously Rubbing the Skin

Scrubbing of the skin can be very much overdone. The outer layer of the skin exists for the necessary purpose of protection. If we rub it away, or reduce its thickness unduly, we simply expose the really living layers of skin that lie below it. Much washing may therefore promote dirtiness in the long run, by unduly exposing the layers of skin in which dirt—above all, living dirt, crammed with microbes—may lodge and cause disaster. Many people, especially children, suffer—at any rate, much irritation and discomfort, if nothing more—from having roughish wool or flannel put upon skin which has been too rigorously scrubbed.

This point especially applies to the face. The skin is here very thin, and unfortunately the face is much exposed to dirt in the air of modern cities. The citizen, therefore, and especially the citizeness, anxious to look her best, washes the face frequently, and very often gives it a good rub, to make it perfectly clean. She uses very hot water, and she rubs off much of the outer layer of the skin. Thus she dilates the blood-vessels, making the face red, and removes much of the white layer which normally screens the red blood. Further, she exposes the warmed and largely denuded skin to all manner of irritant dirt and microbes and sunlight; and unless she is wise in time she will be reduced to enduring a disfigurement, or replacing with powder the layer of useful skin which she has been at pains to remove.

The Best Kind of Soap to Use for the Skin

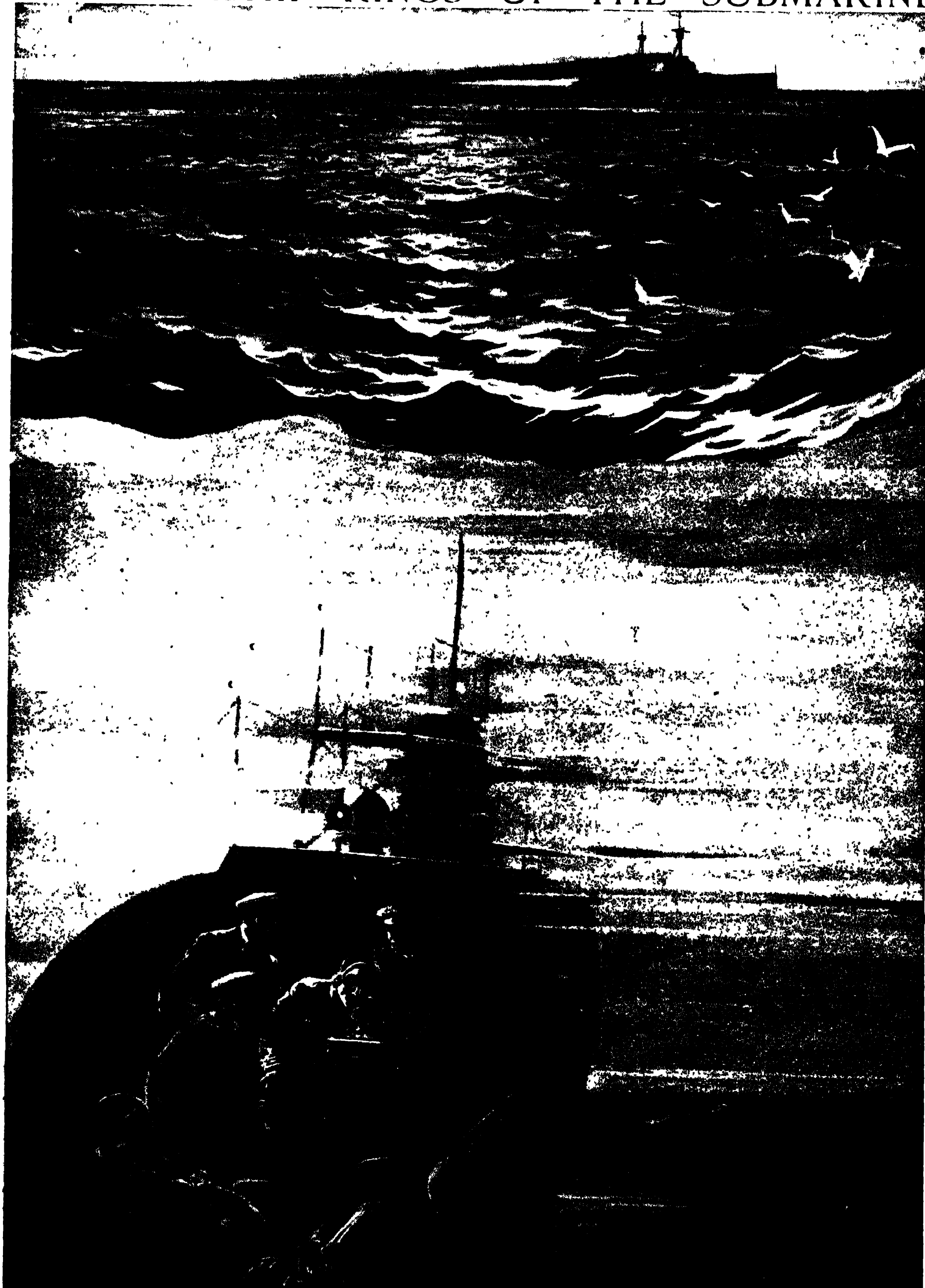
In the ordinary way, only one woman in many who make the mistake learns about it —and that too late, from the skin specialist or the professional purveyors of "beauty." It is better to understand the very simple facts of the case, and treat the skin of one's face with more respect from the first. It can be kept clear and clean without the use of hot water, or scrubbing, or even soap.

Not that soap is to be underrated as a means of cleanliness. Very largely it acts by helping to dislodge and loosen the outer cells of the skin, already ripe for detachment, and thus soap and scrubbing have just the same effect. Also soap acts chemically by dissolving the fats and oils of the skin, and carrying away the dirt which naturally sticks to and lies in these fats and oils. There is also an action of the suds, which is not chemical, but seems to depend on making an "emulsion" of the skin-fats, and so getting them away. These actions are best displayed in an alkaline soap; and there are very few soaps which do not contain a quantity of free alkali on this account, especially as the value is no less for clothes than for the skin. But the skin is unlike any piece of cloth, in that it is alive, and it is apt to resent the use of alkalies, if they be of much strength. It is better to use, for delicate skins, soaps which have been prepared for the purpose, such as "superfatted" soaps, which contain free fat and no free alkali. No soap containing free alkali should be used for the thin and sensitive skin of the face, but only a mild, non-alkaline soap which acts in the third of the three ways we have noted, but not in the other two. It must be remembered that soap is a human invention, and that skin is much older. The skin has its own power of cleansing itself, as no lifeless surface has; and if it be reasonably helped it is more likely to remain well and clean than if it be treated as if it were a metal plate.

The Best Possible Kind of Exercise that We Can Take in Water

Obviously our first principles are all unsound if bathing in the open air is not far superior to anything indoors. All the arguments in favour of the open door, even beyond the open window, apply here, as to every form of exercise, game, or sport. The value of moving air is closely similar to that of moving water—moving because it is in a stream or on a shore, or because we are moving in it, which comes to the same thing so far as the action on the skin is concerned. We ought to aim at personal movement, in water, whether indoors or out, even more than at personal movement in air, because water is colder, being a good conductor of heat away from the body, which dry air is not. The best bathing, therefore, is swimming; and of all the uses and applications of water outside the body, ordinary or medicinal, there is none so good, so natural, so free from drawbacks, or so various in its utility to mind and body, not to mention the lives of others, as we obtain in swimming.

THE WARSHIP RINGS UP THE SUBMARINE



The telephone in the submarine ends with a pair of short wires projecting into the sea. Far away, on the battleship, a similar pair of wires trails from a telephone into the water. The electric current set up when the men in the submarine talk to the men on the battleship travels from the first pair of wires into the sea, and the sea acts as a conductor and carries the current so that it affects the second pair of wires.

TALKING ACROSS THE SEA

The Coming of the Day when We Shall Speak
Across an Ocean as Clearly as Across a Table

DEVELOPMENT OF THE WIRELESS TELEPHONE

We are in a position to announce that, within perhaps one year, Englishmen and Americans will be able to talk to each other over the vast space of the Atlantic Ocean.

This will be done without any cable or other material means of communication. An absolutely new principle has just been discovered: and we hope soon to be able to publish details of the marvellous invention which will enable men to speak to each other across the ocean as easily and as clearly as they now speak across a room.

Already, by means of another system invented by Professor Valdemar Poulsen of Copenhagen, it is possible for a man in England to talk to a man in Denmark, merely by speaking into an electric arc lamp. There is no cable, no wire of any sort; only one lamp at Lingby in Denmark, and another lamp at Cullercoats near Newcastle, England. Above the house, in which the arc lamps burn, rises a sort of huge umbrella-frame, made of wires. It stands about 220 ft. high, and it acts in somewhat the same way as the receiving apparatus in wireless telegraphy. In other words, it collects the spoken messages sent out from the arc lamp some hundreds of miles away. Rome and Messina have also been connected by a wireless telephone.

At present, 325 miles is the longest distance in Europe over which human speech has been transmitted, clearly and distinctly, without any wires; and from America come reports—which perhaps need discounting—of still more startling experiments. Public attention, however, has been so entirely occupied with the lesser marvel of wireless telegraphy that scarcely anything seems to be generally known about the extraordinary progress achieved in the last few years in the master science of wireless telephony.

Yet everything goes to show that the wireless telephone will be triumphant over every other means of communication at a distance. Both in ordinary telegraphy and in telegraphy without wires, human language is translated into a strange, awkward dialect of dots and dashes; and a staff of operators is needed first to turn the message into clicks, and then to translate the clicks back again into written words. No quick and direct question and answer are possible to the public using any form of telegraphy. How different it is, even with the ordinary telephone! There is no means of communication so satisfying as human speech; and it is due to this fact that wire telephony to-day is superior to the older art of telegraphy.

Compare, for instance, the progress made by our Government in its ordinary telegraph service and its telephone service. The telegraph is everywhere worked in the same way, but in some of the telephone systems two persons can get into instant communication with each other without the help of any operator. Below the part of the telephone which they use for speaking and listening is a dial. Round the dial is painted a number of figures, and there is a pointer in the middle which can be set to any figure. By moving the pointer to the figures which represent the telephone number of the person with whom it is wished to talk, communication is at once established with him. Electric currents flow from the dial into the telephone exchange. There they set in motion a marvellous piece of mechanism, which unites the subscriber's line to the line running into the house of the person with whom he desires to talk. No human hand or eye at the exchange does any of the work. This automatic system is now being tried by our Post Office. It is the result of only thirty-six years' progress in

telephony—less than half the number of years devoted to the development of the electric telegraph.

In 1875, forty-eight years after the invention of the telegraph, a young Scotsman, Dr. Alexander Graham Bell, said to a friend, "Mr. Watson, come here; I want you." He was talking in a noisy machine-shop in a narrow street in Boston, in the United States. Up three flights of stairs from the basement to the shop rushed Watson, breathless and wild with joy.

"I can hear you!" he shouted as he burst into the room. "I can hear the words!"

The Young Scotsman who Made the Modern Telephone Possible

Such was the historic birth of the new science of transmitting speech by electricity, which now promises to transform entirely our means o communication throughout the world. If, as is expected, men will be able to talk next year across the Atlantic, a message of congratulation will surely be sent to Dr. Bell. For it was he who made modern telephony of every kind possible and practical. He began experimenting in 1872 in America. At that time he was already well known as the inventor of an excellent system for teaching the art of speech to deaf people. His special interest in speech was indeed the source of his inspiration. He was trying to devise an instrument for making speech visible, with a view to enabling the deaf to *see* what was said to them.

It took him two years to construct a crude machine. He placed two magnets at a distance, and connected them with a wire; in front of the first magnet he put an iron reed, and behind the second magnet he put another reed. The first reed vibrated under the influence of sound waves created in the air when anyone talked. Its vibrations affected the magnet, which then sent a current of electricity along the wire; and this current varied according to the way in which the vibrating reed swung towards and from the magnet.

How a Man's Voice was Made to Set Up a Disturbance in the Ether

When the varying current reached the second magnet at the far end of the wire, it changed the attractive force of this magnet. When the magnet became stronger, the iron reed behind it was bent towards it; and thus a second series of vibrations was set up in the second reed, answering to the vibrations produced in the first reed by the sound-waves.

In other words, the power of the human voice produced waves in the air; these waves were actual, material waves, like waves in water, the only difference being that they could not be seen. The iron reed vibrated under their influence in a way somewhat similar to that in which a reed would tremble in a breeze. When, however, the iron reed in its vibration approached the magnet—which was really an electro-magnet—it set up a current of electricity. In this manner a sound-wave in the air was utterly transformed into a disturbance in that mysterious medium the ether, which fills the whole universe, stretching between the vast airless and apparently empty spaces between star and star, and underlying and penetrating all forms of matter.

Dr. Bell had thought out his machine only with a view to making sound visible in the vibrations of the iron reeds. He wanted to improve the reeds so that the deaf could see the vibrations very clearly, and could then study the vibrations until they understood what sounds these represented. By this means he reckoned they could be taught to see what was said to them. But the sight of the two reeds, vibrating in unison, suddenly set his mind working in another direction. The idea of a telephone was then born.

The First Telephone Message that Came Through the Ear of a Dead Man

This is how it came to Dr. Bell. He knew that the drum of the human ear was a vibrating instrument. When waves of sound travelled through the air to it, they made the membrane vibrate in the same way as they made the iron reed tremble. Dr. Bell worked all this out, with the ear of a dead man. At the back of the ear he placed a straw, that touched with one end the ear-drum; the other end of the straw was set close to a piece of smoked glass. Bell spoke into the ear, and the vibrations of the drum acted on the straw, which, in turn, made tiny markings upon the glass. Out of this rather gruesome experiment came the great discovery. The telephone was actually born in the ear of a dead man.

For Dr. Bell had observed that, though the human ear-drum was small and thin, it could send, in an effective manner, through heavy bones, the thrills and vibrations representing all the modulations of human speech. "If this tiny disc can vibrate a bone," he said to some friends, "then an iron disc ought to be able to vibrate an iron rod, or an iron wire at least."

A SCENE AT A TELEPHONE EXCHANGE

The busy hands of many operators are needed to work an ordinary telephone exchange. Each subscriber's line ends in a socket, and the operator uses a short, detached line, with a plug at the end, which can be fitted into the socket. By this means she communicates with the subscriber, and connects the socket of his line with the socket of the line he inquires for. Such a busy scene as this may one day disappear if the automatic exchange should succeed.

His friends laughed at him; two rich men, who had been assisting him with money in his experiments, refused to have anything more to do with him unless he kept to his old ideas; and the man whose daughter he was engaged to marry said he would refuse to allow the marriage to take place, unless Dr. Bell abandoned the "foolish telephone."

The Poor Inventor who Spent All His Money in Working Out His Ideas

The young inventor was extremely poor. He had given up a professorship in Boston University, and spent all his money in working at his ideas. Nevertheless, he went on constructing a telephone for forty weeks—forty long, exasperating weeks, for the instrument would do no more than gasp and make strange, inarticulate noises. But at last it talked; and on March 10th, 1876, it said distinctly: "Mr. Watson, come here; I want you." Day by day the tone of the baby instrument grew clearer, a new note in the orchestra of civilisation, and one destined to become the most powerful of all.

So, on his twenty-ninth birthday, Dr. Bell was able to take out his patent, which has proved the most valuable single patent ever issued in any country. He had created something so entirely new that there was no name for it in any language; and in describing it at the patent office he was obliged to call it "an improvement in telegraphy." As a matter of fact, it was as different from the telegraph as the varied, flexible, and infinitely expressive eloquence of a great orator is different from the sign-language of a deaf-mute.

Two months after the young inventor received his patent, his telephone was shown at an exhibition in Philadelphia. There it was displayed for six weeks without attracting any attention. Some judges were, indeed, laughing at it when the Emperor of Brazil walked into the room with a troop of courtiers. With outstretched hands, the Emperor came forward, saying: "Professor Bell, I am delighted to see you again!"

The Emperor who was Staggered by the Machine that Talked

The interest of the judges was at once excited in the young, pale-faced inventor, who was apparently on terms of friendship with an Emperor. Instead of passing away from the telephone without examining it, they waited to see what would happen.

The Emperor of Brazil was especially interested in humanitarian work; and some years before he had visited Dr. Bell's class of deaf-mutes at Boston University, with a view to founding a similar class at a school in Rio de Janeiro. Dr. Bell now asked the Emperor to put the receiver to his ear, and he went himself to the transmitter at the far end of the room. No one knew clearly what was about to occur, and the assembled judges and men of science—fifty in number—waited expectantly.

"*My God! it talks!*" cried the Emperor, raising his head from the receiver, with a look of amazement.

"It is the most wonderful thing I have seen in America," said Lord Kelvin, who followed the Emperor of Brazil in listening at the receiver. "It does speak."

One after another the company of brilliant and distinguished men listened to the voice of the first telephone; and the more they knew of science, the less they were inclined to believe their ears. The greater their knowledge, the greater was their wonder. The young teacher of deaf-mutes had given the human race a marvellous extension of the power of speech and the power of hearing. At the present day, Dr. Alexander Graham Bell is a very wealthy man; and by means of his invention, men are able to converse with each other from New York to Denver, separated by a space of 2000 miles.

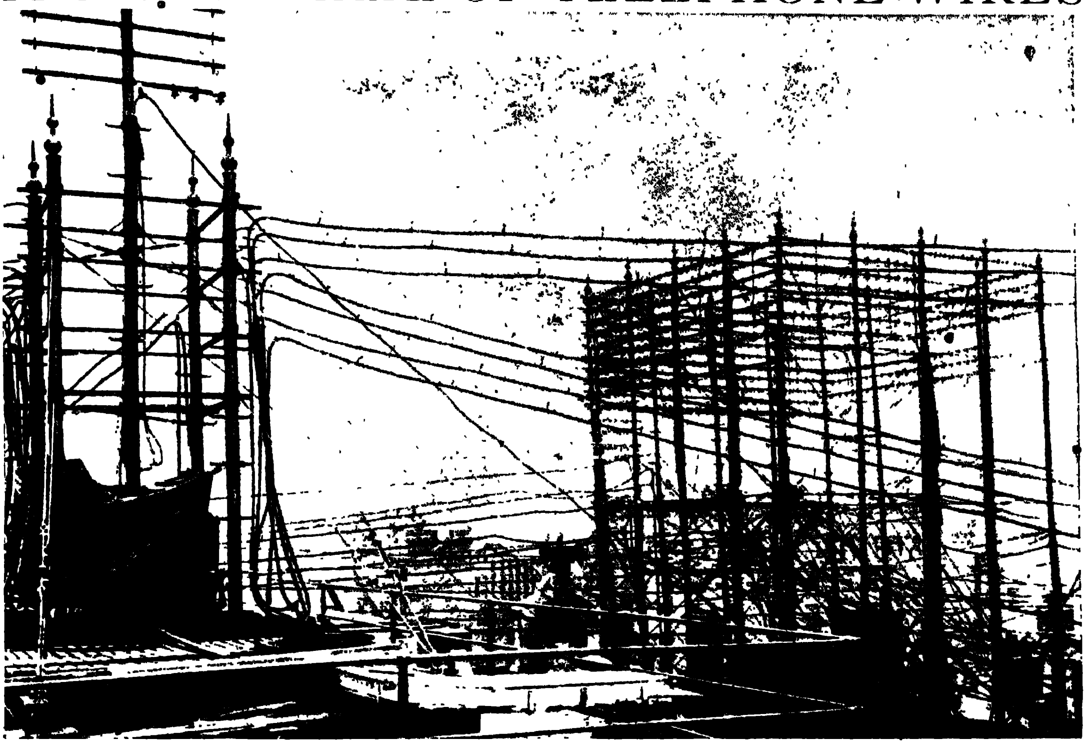
Will the Prime Minister Sit at Westminster and Talk to the Empire?

Perhaps, in less than ten years, it will be possible for a Prime Minister of England to talk in turn with the Prime Ministers of all our Colonies, he sitting in his room in Downing Street, and they in their houses in the capital cities of their dominions.

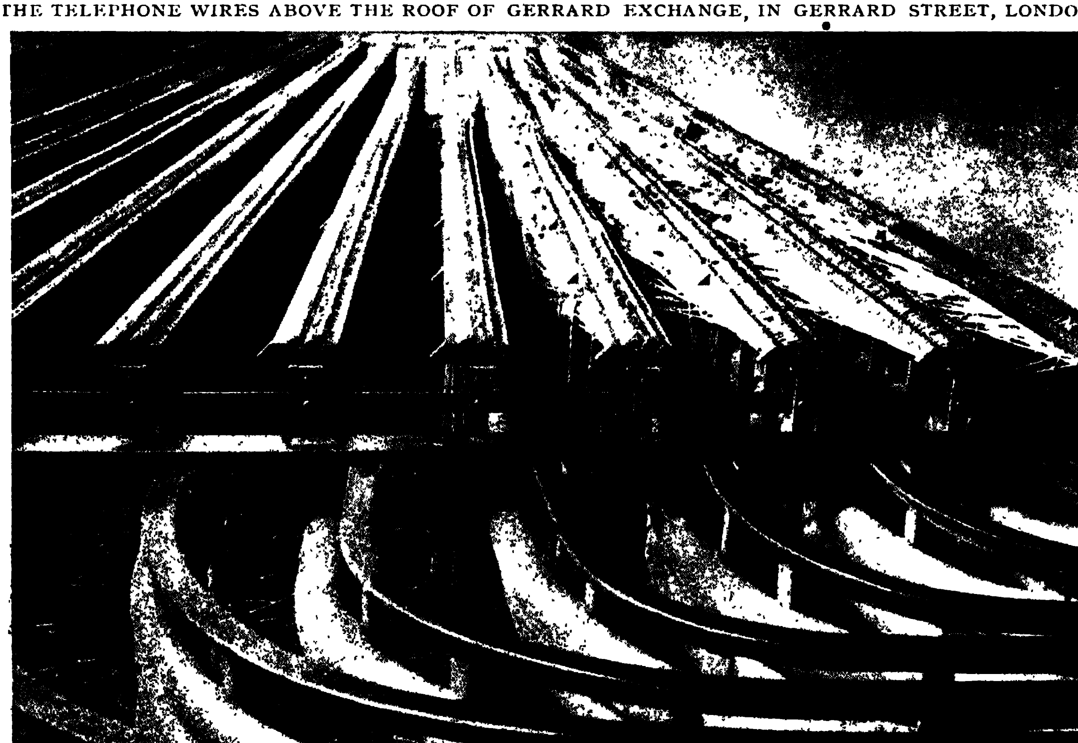
The telephone is founded on two simple things. Sound is heard by means of waves in the air, which create vibrations in the drum of the ear. Dr. Bell made a thin iron plate which vibrated to sounds in the same way as does the membrane of the human ear. He placed this iron membrane close to, but not touching, an electro-magnet. From the magnet ran a copper wire which was connected with a similar electro magnet; close to this was placed another iron membrane. Words spoken against the receiving membrane made it vibrate, just as the iron reed vibrated. The vibrations moved the membrane towards and from the electro-magnet. This set up an electrical current, which ran along the wire and affected the second magnet. This second magnet began to attract and repulse the second iron membrane.

Now comes the extraordinary thing. As the membrane vibrated under the action

THE VAST MAZE OF TELEPHONE WIRES



THE TELEPHONE WIRES ABOVE THE ROOF OF GERRARD EXCHANGE, IN GERRARD STREET, LONDON



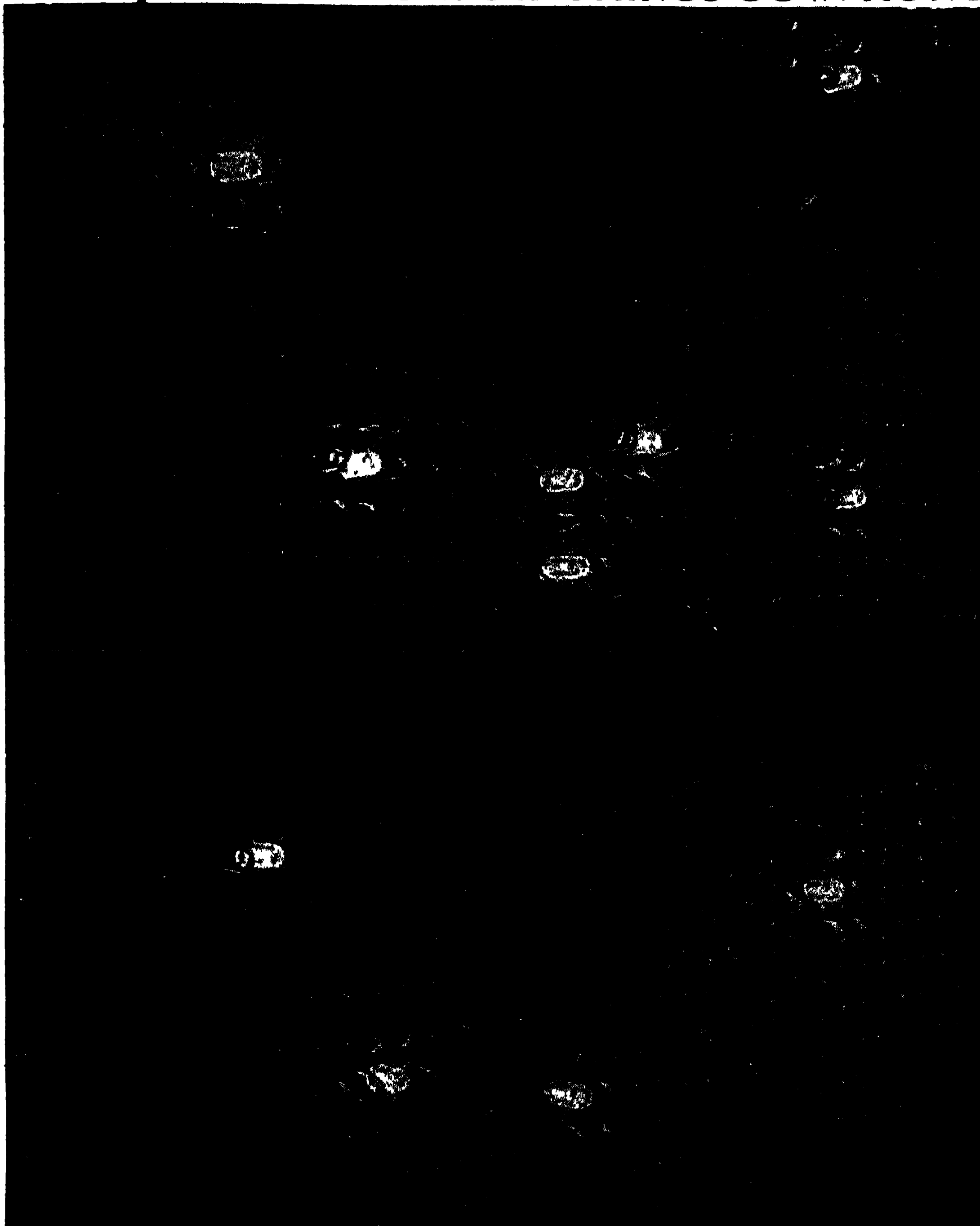
THE RACKS HOLDING THOUSANDS OF TELEPHONE WIRES AT PADDINGTON

A few years hence we shall no longer be able to gaze up at the network of telephone wires which overhang our streets in thousands. The modern system, shown below, is to run the wires underground in cables, which may contain as many as six hundred wires as they enter the exchange.

THE MACHINE THAT PUTS US THROUGH

The Post Office is now experimenting with a new automatic telephone exchange, which has been a great success in America, in which no operator is required The subscriber indicates on a dial on his telephone the telephone number he requires Electric currents then travel from the dial to the exchange, and there set in motion a wonderful mechanism which performs all the work of connecting the two lines

THE LAMP THAT BURNS IF THINGS GO WRONG



This is part of the "Fault" Board of a large Post Office Exchange. It consists of ranges of tiny lamps, each connected with the wire of one subscriber; if anything goes wrong with the wire, and the electric circuit is broken, the lamp is suddenly lighted. So perfect is the present telephone system that for long periods no lights now shine on the fault board, though some are shown here to indicate the system.

of the magnet, it moved the air and produced waves in it—not waves of electricity, but actual, material waves of air. That is to say, it produced sounds, and these sounds were a reproduction of the very sounds which had set the first membrane vibrating. To put the whole thing in another way: waves of sound in the air are transformed into an electrical current; this current can be sent along a wire two thousand miles in length. It is then set to act on a magnet, and this magnet acts on an iron membrane, and by this means the electrical current is converted back into waves of sound.

How the Telephone Transformed the Human Voice into an Electric Current

In short, Dr. Bell, by means of his telephone, first transformed mechanical energy —the energy of the human voice—into an electrical current. He sent this current along a wire, and at the end of the wire he retransformed the electricity into the mechanical energy of speech. This point is worth going into, for it shows that, in making his telephone, Dr. Bell used the same principle as is now universally employed in running electrical trams and trains, and driving the electrical machinery in modern factories and engineering yards.

Everybody has seen a steel magnet pick up a bit of soft iron. A curious effect is produced if the bit of iron is not allowed to touch the magnet, but is only placed near to it, and then rapidly moved. The result can be seen by winding a copper coil round the end of the magnet, the coil ending in a long wire of copper some hundreds of miles in length. When the iron is moved near the magnet an electrical current flows down the wire. This is how electricity is manufactured at waterfalls, and in the great electric power-stations of our great cities.

The Little Dynamo Set Going when Dr. Bell Spoke Into His Telephone

The piece of soft iron is fixed at the end of a shaft driven by water-power, steam-power, or gas-power; and close to the end of the shaft where the soft iron projects is placed a magnet with a coil round it, and a wire leading from the coil. As the piece of iron spins round on the shaft, a current of electricity flows from the coil of the magnet down the wire. Instruments of this sort, which turn mechanical work into electrical energy, are called dynamos.

Now we can understand clearly the first part of Dr. Bell's telephone into which he talked. The sound-waves of the human voice made the membrane of soft iron vibrate. One twenty-fifth of an inch away from the membrane was a steel magnet with a coil of wire round it. As the membrane moved to and fro under the influence of the sounds produced by the human voice, it created a current of electricity in the wire-wound magnet. In short, the mouthpiece of the telephone was a little dynamo, worked by the energy of human speech.

The receiving apparatus at the other end of the telephone was identical in construction, but it worked in quite a different way. In factories driven by electrical power the current enters on a small copper wire. This wire is connected with the coil round a magnet. Very close to the magnet is a piece of soft iron fastened to the end of the shaft. When the electric current affects the magnet, the magnet in turn moves the piece of soft iron, and imparts a motion to it.

The result is that the shaft, in which the iron has been fixed, spins round, and works all the machinery in the factory. The wheels of electric motor-cars, trams, and trains are made to revolve in a similar way. There is an active magnet receiving an electrical current; and close to the magnet, but not touching it, is a piece of soft iron which turns round and imparts motion to the driving gear.

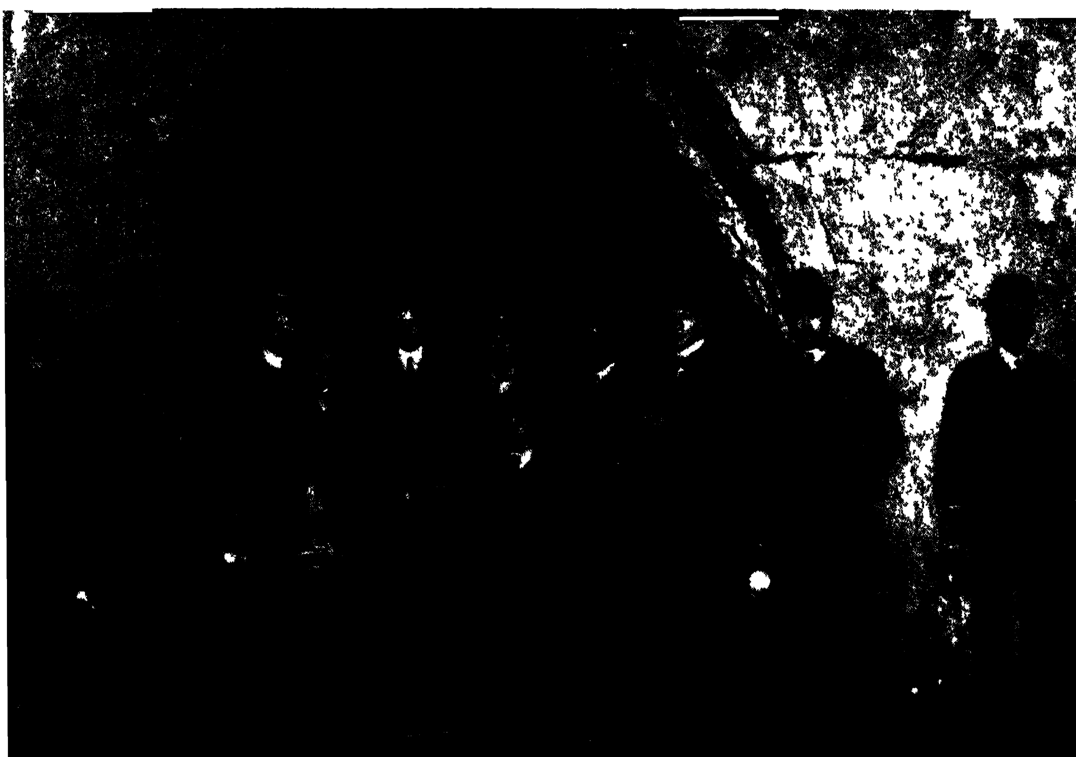
The Receiver which Changes the Electric Current into Speech again

It is really a dynamo with a sort of reverse action. Instead of converting mechanical power into electrical energy, it transforms electrical energy back into mechanical power. The technical name for it is an electric motor.

Now, the receiving part of Dr. Bell's telephone—the part he put to his ear when someone was speaking at the other end of the wire—was practically a little electric motor. It transformed the electrical current into mechanical power. When the current affected the magnet, and made the magnet strong, the membrane of soft iron, fixed only one twenty-fifth of an inch away, was attracted inwards. When the current in the magnet became weak, the membrane of iron sprang backwards. In this way many thousands of extraordinarily slight movements were imparted every second to the membrane, and the result was a series of continual and exquisitely delicate vibrations which created tiny air-waves. When these air-waves struck on the ear-drum of Mr. Watson on March 10, 1875, they reproduced the human speech of Dr. Bell which had acted on the little dynamo forming the mouthpiece of the telephone.

A WIRELESS MESSAGE THROUGH THE EARTH

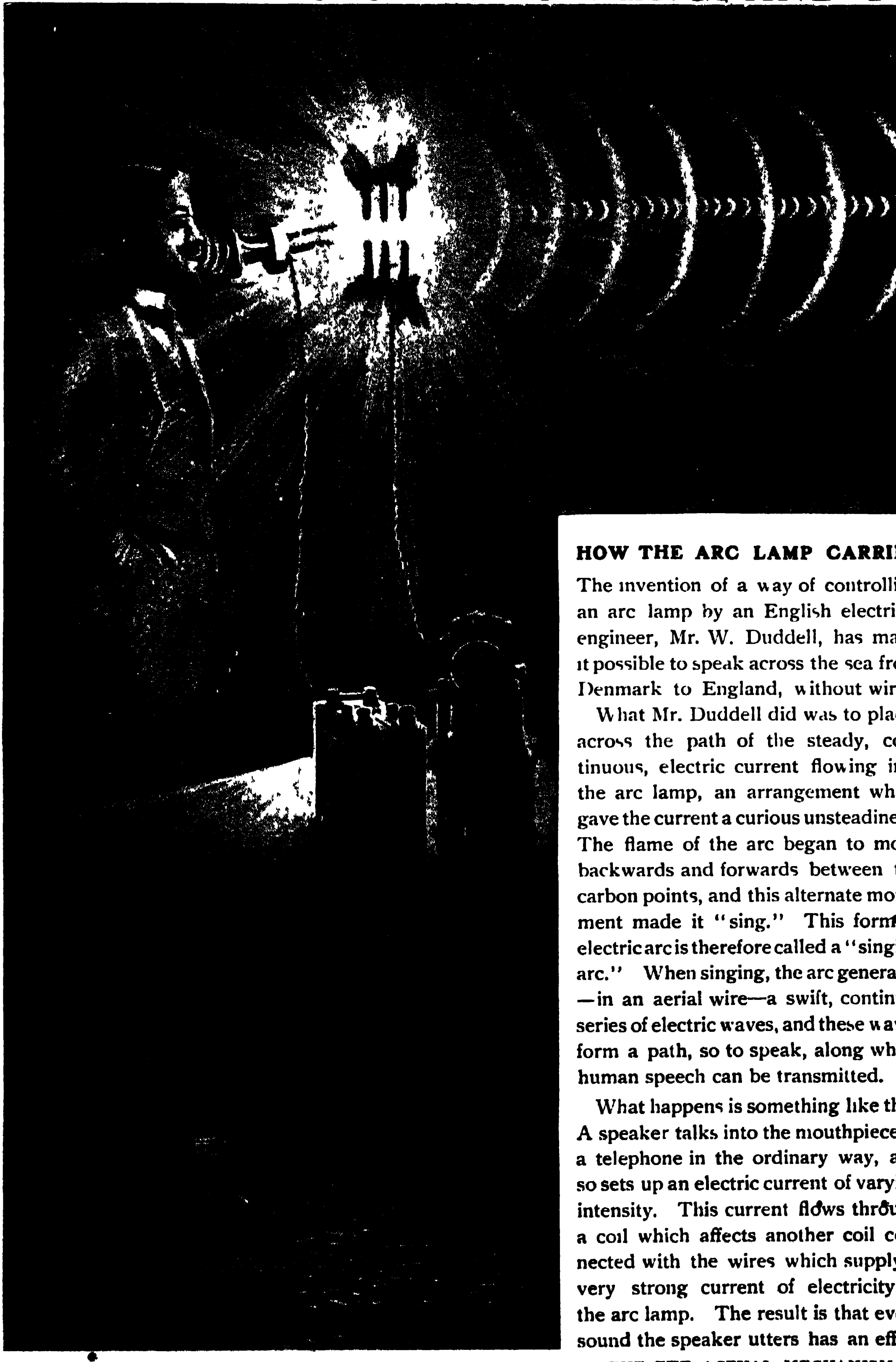
THE PORTABLE TELEPHONE THAT TRANSMITS SPEECH WITHOUT WIRES



RECEIVING A MESSAGE TRANSMITTED BY WIRELESS TELEPHONE TO THE CAVES UNDER CHISLEHURST

These portraits of an experiment recently conducted in the Chislehurst Caves show how important to miners is the latest invention in telephoning without wires. By means of two light, portable instruments, speech was transmitted from the hilltop to a cave nearly a mile away. The two instruments are fixed in the earth, and the earth conducts the electric current from one instrument to the other.

HOW A MAN SPOKE FROM ENGLAND TO



HOW THE ARC LAMP CARRIES

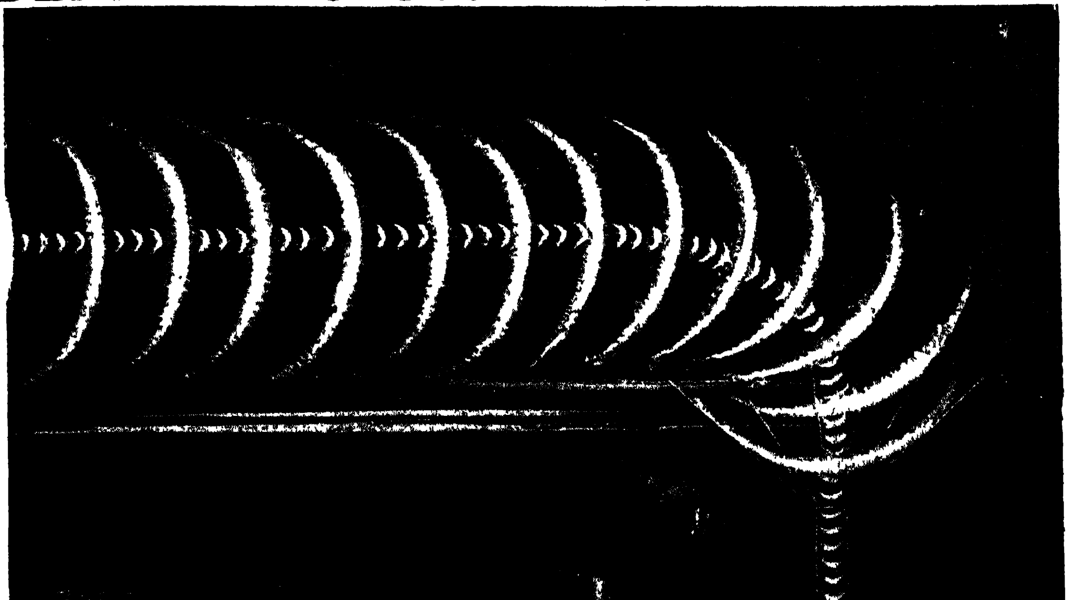
The invention of a way of controlling an arc lamp by an English electrical engineer, Mr. W. Duddell, has made it possible to speak across the sea from Denmark to England, without wires.

What Mr. Duddell did was to place, across the path of the steady, continuous, electric current flowing into the arc lamp, an arrangement which gave the current a curious unsteadiness. The flame of the arc began to move backwards and forwards between the carbon points, and this alternate movement made it "sing." This form of electric arc is therefore called a "singing arc." When singing, the arc generates —in an aerial wire—a swift, continual series of electric waves, and these waves form a path, so to speak, along which human speech can be transmitted.

What happens is something like this. A speaker talks into the mouthpiece of a telephone in the ordinary way, and so sets up an electric current of varying intensity. This current flows through a coil which affects another coil connected with the wires which supply a very strong current of electricity to the arc lamp. The result is that every sound the speaker utters has an effect

THIS PICTURE-DIAGRAM DOES NOT, OF COURSE REPRESENT THE ACTUAL MECHANISM OF

DENMARK ACROSS THE GERMAN OCEAN



on the oscillations of the singing arc. What is more important, from the point of view of wireless telephony, is the fact that the electric waves become disturbed, and the disturbances represent, in a very exact way, the sound-waves made by the speaker in the mouthpiece of the telephone, which are transformed by the telephone into electric energy. The disturbances are very slight; only about one twentieth part of the stream of electric waves from the arc lamp is affected by the current coming from the telephone.

Yet, by means of a receiving apparatus, it is possible, at a distance of three hundred and more miles, to use the slight disturbances in the ripple of electricity, and change these disturbances back into the speech which started them. An ordinary telephone receiver, with special modifications, is used, the effect being to allow only the slight disturbances to affect the magnet in the telephone receiver. The magnet makes the iron membrane vibrate, and the vibrations result in sound-waves exactly reproducing the speech of the speaker in the receiver at the other end—across, say, the German Ocean.

THE TRANSMISSION, BUT IS DRAWN TO SHOW THE MAIN PRINCIPLE IN SIMPLIFIED FORM

Of course, the whole energy of human speech is not reproduced in the air-waves that come from the receiver of a telephone. Some energy is lost at the mouthpiece, where speech is turned into electricity. A loss again occurs in the current as it travels along the wire: and some of the energy is also lost in turning the electrical current back into the mechanical power of speech. These three sources of loss had to be diminished before Dr. Bell succeeded in making the telephone into the new and practical force in civilisation that it is to-day.

The Microphone into which we Speak Our Telephone Message

The most striking improvement was effected by Professor E. D. Hughes, a London inventor, who made a large fortune in America, which he left to the hospitals of his native city. Professor Hughes saw that the weak point in the telephone was the mouthpiece. Too much of the power of human speech was expended in creating an electrical current. That was why the sounds reproduced at the other end were very faint, even at a short distance. Too much was being asked of the human voice, and Professor Hughes made its part of the work easier by the invention of a new kind of mouthpiece, which is now widely known as a microphone.

All modern telephone mouthpieces are microphones. They are fitted with a thin membrane, resembling the thin sheet of iron that Dr. Bell first used, but behind this membrane there is no electro-magnet to act as a dynamo. The electrical current is manufactured by the Government or company working the telephone system, and it is present in the microphone. It cannot, however, be used, because between it and the membrane is a little box filled with grains of carbon.

What Happens in the Little Box Behind the Mouthpiece of the Telephone

These grains of carbon are packed very loosely together: and while they remain in this loose condition they prevent the current of electricity from getting into the telephone wire which runs to the exchange.

The most delicate pressure on the membrane, however, serves to bring the tiny grains of carbon closer together. When we speak into the microphone —generally called the transmitter—the sound-waves which our voice makes strike against the membrane: and as this vibrates, it presses the grains of carbon together in very slightly varying degrees. So a varying amount of electricity then passes through the powdered carbon, and flows along the wire. It goes through the telephone exchange, where it is connected with the wire running into the house of the man to whom we are talking. He puts the receiver of the telephone to his ear; and there the electric current acts on a magnet, just as it did in the original telephone, and makes a thin iron sheet vibrate and give out sound-waves.

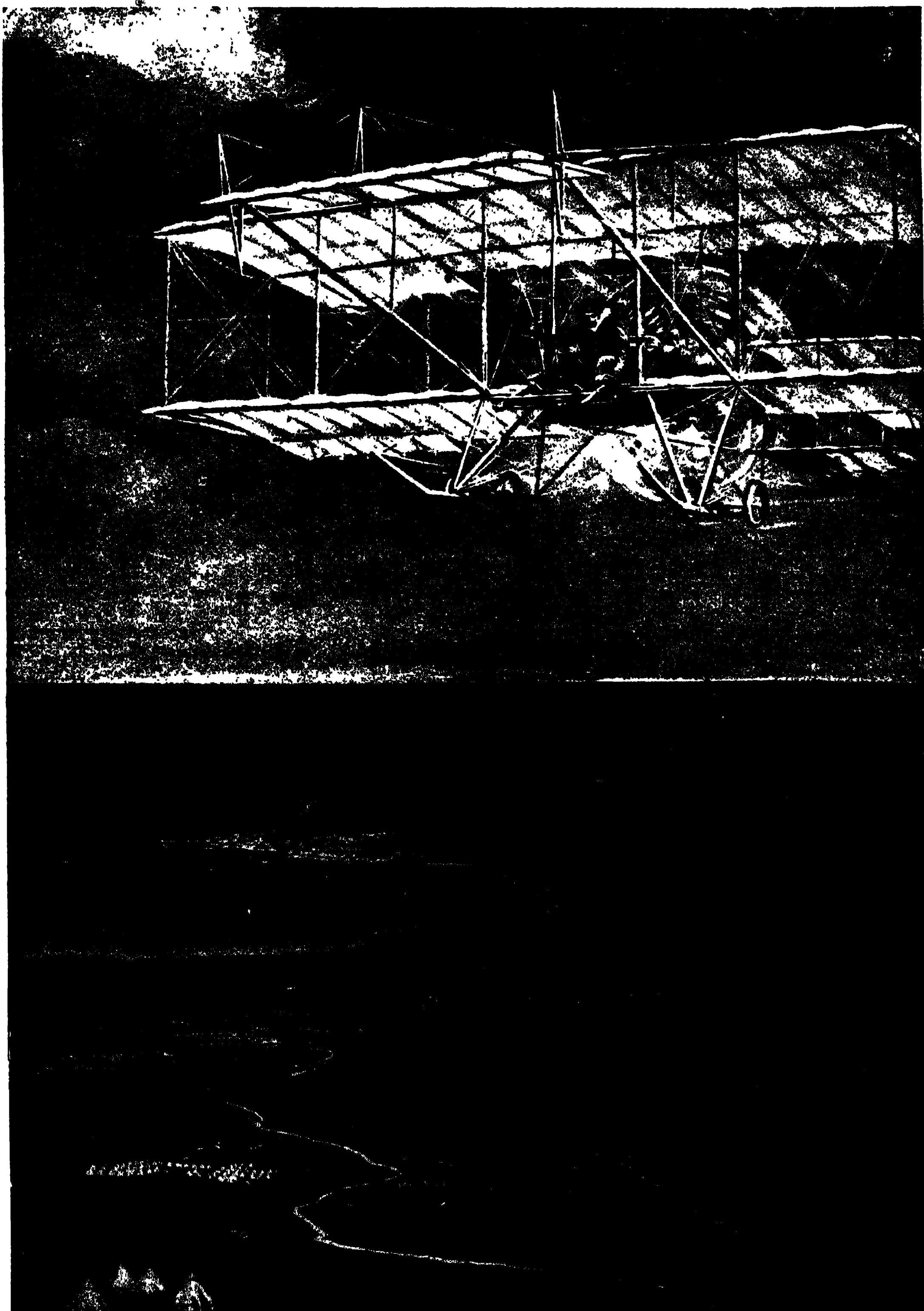
Both the mouthpiece and the receiver of the ordinary telephone have been developed in a marvellous manner, but the old trouble with the electric current itself still remains. The longer the wire, the weaker the current grows. That is why the telephone at present has, at its best, only about a third of the range of the wire telegraph. It is possible to telegraph from London to Teheran in Persia—six thousand miles; while the two thousand miles between New York and Denver form the longest distance yet covered in the transmission of speech. And this was only an experiment conducted with great difficulty. In a practical, commercial way, the telephone line between New York and Chicago, at a distance of about a thousand miles, is the best piece of telephone work yet done. Every day a tremendous amount of business is carried on over this long-distance line.

The Wonderful Current that Must Reproduce All the Subtleties of the Human Voice

When a submarine cable is used for the transmission of speech, the difficulties are much increased. Only of late years was it possible to construct a short cable which would enable a man on the English shore to distinguish clearly what a man was saying, twenty-one miles away, on the shores of France. A telegraph current has only to make a click in the receiving apparatus in order to carry a message. A telephone current, on the other hand, has to reproduce all the subtle and rapid inflexions of the human voice. The various little weaknesses which affect a current when it is travelling a long distance over a telegraph wire do not interfere with its straightforward, easy work of making a series of clicks at the end of its journey. Human speech, however, becomes distorted out of all recognition when the electrical current which carries it grows weak or lags on its journey.

This curious lagging occurs much more in submarine cables than in land wires; and it is only recently that it has been partly overcome on the Paris-London telephone by inserting in the cable at regular intervals

TALKING TO A MAN IN THE SKY



With a wireless telephone instrument called an aerophone, a flying-man at Cardiff recently was able to hear the sound of the human voice above the roar of the engines and the howling of the wind. He was rushing through the air at nearly a mile a minute, but, swift as he was flying, the electric transmission of speech was swifter, and he caught the voice of a friend on the earth below him.

little coils of wire wound in a special way. These coils are known as Pupin coils, from Professor Pupin, who worked out some years ago the principles on which they are based.

It is the Pupin coil which has made the long-distance lines used in America a practical success. They enable telephone engineers to use a thick wire. In itself a thick wire is an excellent thing, as the current that goes over it is not weakened as much as it would be in going over a thin wire. By using a thick wire, however, an electrical engineer used formerly only to get from one trouble into another. On the one hand, the current met with less resistance, and thus did not become weak. On the other hand, it lagged more on the thicker wire, and came out so slowly at the far end that, when it was reconverted into sound-waves, the words were utterly unintelligible. By means of the Pupin coil, however, this slowness has been overcome, and the wire telephone is rapidly extending its range. A few weeks ago it became possible to telephone from London to Switzerland and Germany. Thus one by one the troubles are being avoided; and it is now likely that we shall soon be able to speak over a wire at a distance of four thousand miles or more.

The Remarkable Instrument which Records a Telephone Message

One of the most remarkable of recent inventions in connection with the telephone is the telephonograph of Professor Pierluigi Perotti. With this instrument attached, a telephone combines the advantages of transmitting human speech with the slower but more lasting record of a telegraphic message. The great defect of the telephone is that the person who is rung up is sometimes found to have left his home or his office. The telephonograph removes this defect. It is a sound-box fitted to an air-tight tube, which connects it with the telephone receiver. The sound-box consists of a membrane of mica stretched over a circle of metal. When the telephone-drum vibrates with an electric message, the membrane of mica vibrates in correspondence with it. On the mica membrane is fixed a small metal rod with a sapphire point, just like that used in a phonograph. This point records, on a wax cylinder revolving beneath it, the speech-sounds transmitted to the mica membrane.

There is a second telephone receiver, so that one can listen through it in the ordinary way, or take a permanent record of the speech, or do both of these things at the same time. But if a business man leaves his office for, let us say, lunch, he merely sets the telephone, so that anyone ringing him up in his absence will talk into the recording device, and leave the message written on the wax. The recording cylinder only works when a message is being delivered. A series of trials with the telephonograph has been made over some of the Italian State telephone lines. The instrument was found to be very sensitive and generally useful, and it worked quite satisfactorily in the hands of subscribers.

The Automatic Telephone that Does the Work of an Exchange

Still more marvellous is the improvement which three brothers, George William, Egbert, and Hoyt Lorimer, of Brantford, Ontario, have worked out. These three young Canadians are said to have started without any telephone training and without having seen the inside of a telephone office. Yet they worked out a complicated piece of machinery, absolutely practical in design, which does all the work of a small telephone exchange. No operators are needed to connect the line of one subscriber to the line of the person with whom he wishes to talk. The whole telephone system is automatic. The subscriber marks on a dial fixed on his own machine the telephone number of the person to whom he wants to speak.

Electrical currents travel from his instrument to the exchange, where an intricate piece of mechanism is already supplied with power, and only waiting for a slight electrical impulse to direct its workings. When the impulse arrives, it guides the machine to the exact wire with which the subscriber desires to be connected. If the wire is free, the machine makes the connection; if the wire is engaged, it informs the subscriber of this fact by sending an electrical current which makes a buzzing noise in his telephone.

The Dream of the Wireless Telephone of the Future

This automatic telephone is now widely employed in Canada, and a somewhat similar system by another inventor is used in the United States. Our Post Office is now experimenting with the automatic system.

Superhuman though the automatic telephone seems in its ingenuity, it does not represent the highest reach of inventive genius in telephony. Wonderful it is in conception, and amazing in use, and extraordinary are the powers with which it endows the human voice. But some of the best men of science have begun to dream of

TALKING BY TELEPHONE FROM A TRAIN

The wireless telephone is being adapted to trains in rapid motion, by making the electric current "jump" eighteen inches from the train to a line along the track. This will add not only to the comfort but to the safety of train travel, for trains will be linked by wireless telephony, so that, when one draws too near another, the telephone bell will give the alarm.

a still more marvellous instrument for the transmission of human speech.

"The day will come when copper wires, guttapercha covers, and iron bands will be found only in museums. Then a person who wishes to speak to a friend, but does not know where he is, will call with an electrical voice which will be heard only by him who has an electric ear tuned to its vibrations. The man will cry: 'Where are you?' Quickly the answer will sound in his ear: 'I am exploring the depths of a coal-mine in China. Where are you?' The inquirer may in turn answer: 'I have spent my holiday climbing up the summit of the Andes.' Or perhaps the first inquirer will receive no reply, and he will then know that his friend is dead."

These words are cited by Professor Ernst Ruhmer, of Berlin, in his famous work on "Wireless Telephony." They form the last passage in that work, and they are taken from a book by an Englishwoman, Mrs. Ayrton, the author of "The Electric

Arc "—a subject that few would suspect of having any bearing on the future of wireless telephony.

Everybody is acquainted with the electric arc lamp. Usually two rods of carbon, made of compressed soot or lampblack, are placed in a glass case, and connected by means of a wire with a supply of electricity. When the ends of the two carbon rods are brought together, and a current is made to pass across the junction, nothing remarkable happens. If, however, the carbon points are then separated, heat is at once developed to an extraordinary degree, and a vivid light forms an arc between the ends of the two carbon rods.

This is the arc lamp widely used in lighting streets and large buildings throughout the world. It is also employed in scientific laboratories, for it is the most terrific source of regular heat that man is able to devise. The heat of boiling water is 100 degrees centigrade. The heat created by a current of electricity at the end of a carbon rod is sometimes 4000 degrees centigrade. Heat so terrific as this must need enormous energy for its creation; and considerable energy in the electrical current is indeed required to generate it.

How the Electric Arc Lamp is Used to Transmit Human Speech

The heat of an electric arc, however, is not the most wonderful feature about it. Far beyond the range of the heat and the dazzling light which the electric arc produces go the electric waves which are generated in the flame between the two carbon points.

It is by means of these electrical waves of the arc lamp that speech has been sent over a distance of three hundred and twenty-five miles; and here we come to the fact on which Mrs. Ayrton and Professor Ruhmer base their prophecies. Speech transmitted without wires by means of the waves of the electric arc lamp is better than the speech transmitted by the ordinary wire telephone. It is freer from the distortion caused by the lagging of the electric current on the wire; it is clearer and more distinct. That is why, as Nikola Tesla said, " we shall soon be able to speak across the ocean as easily as we now speak across the table."

It is very pleasant to find that it was an English electrical engineer, Mr. W. Duddell, who made the original discovery of the possibilities of the arc lamp. This he did in 1900, by his invention of the singing arc. In a singing arc a steady, continuous current of electricity is made to act in a manner somewhat similar to that in which a steady current of air acts in an organ-pipe. Connected with the organ pipe is a vibrating instrument through which the current of air passes. This makes the air oscillate, and the result is a pure musical note. What Mr. Duddell did was to place, in the path of the steady, continuous current flowing into the arc lamp, a thing called a condenser, which gave the current a kind of regular unsteadiness. The flame of the arc began to move backwards and forwards between the carbon points, and this alternate movement made it sing. The note depends on the number of oscillations, and can be "tuned" by varying the capacity of the condenser.

The Difference Between Wireless Telegraphy and the Wireless Telephone

But what was more important was the fact that the oscillations sent out from the arc of flame an incessant stream of electric waves, undulating through the ether for hundreds of miles. It is by means of these electric waves that sounds of the human voice are conveyed over long distances clearly and more distinctly than a submarine telephone cable would transmit them. The whole energy of the continuous flow of waves, however, is not used.

This is the chief difference between wireless telegraphy and wireless telephony. Marconi needs only an instrument which will dart a single electrical impulse across the world. By repeating at various intervals this single impulse, he is able to signal a message. But these single, intermittent impulses, created by sending a momentary spark from an electrical machine, are utterly useless in telephone work. It is impossible to get a sufficiently rapid succession of sparks which will convey the swift, subtle modulations of human speech.

A Path for the Voice to Travel in on Its Way Across the German Ocean

A musical note corresponding to the fundamental tone of a speaker's voice has been transmitted by the spark method, but all the character of language was lost. When the length of the spark is shortened with a view to make it still more rapid, an electric arc is produced which is inactive and not oscillating.

The singing, oscillating arc that Mr. Duddell invented sends across the ether a quick, unbroken series of ripples. These ripples are closer together than the waves that our voice makes in the air. They form, so to speak, a path along which the inflexions of our voice can be sent. The way in which this is done is very wonderful. The speaker

talks into the mouthpiece of a telephone in the ordinary way, and the words are transmitted in the form of electrical energy through a coil of wire. This wire, however, is made to influence the current which supplies the arc lamp. The result is that every sound that the speaker makes has an effect on the oscillations of the flaming arc. It sings in answer to the voice, for it is an exquisitely docile pupil. It can reproduce tunes played to it on the flute or the violin, or sung to it by the voice—hence its name of the singing arc.

The Troubled Ripples in the Air which can be Changed to Human Speech

But more important than the singing of the flame is the change in the stream of waves that it is sending through the ether. The waves become disturbed; and the disturbance represents, in a very exact way, the sound-waves made by the speaker in the mouthpiece of the telephone, and there transformed into electric energy. The disturbance is slight, only about one-twentieth part of the continuous stream of arc-lamp waves being affected by the current coming from the telephone. Yet by means of a receiving apparatus it is possible, at a distance of three hundred and more miles, to use the slight disturbance in the ripple of electricity, and change this back into the speech which originally provoked it.

An ordinary Bell telephone receiver can be employed in a modified way. The main stream of electric waves is balanced by a local set of similar vibrations created in the receiving station, so that only the disturbances are allowed to affect the membrane of the Bell telephone receiver. They act on an electro-magnet, and this makes the membrane vibrate; the vibrations produce sound-waves, and the listener hears what a man is saying far across the sea.

The Wireless Telephone that can be Carried About

There are several practical methods of talking over a few miles without using wires. Just recently Mr. A. W. Sharman has invented a wireless telephone of this sort, which weighs only about six pounds, and can be easily carried about. Imagine what a benefit this little instrument will be to men working in the sombre, perilous depths of a mine, where if an explosion now takes place the ordinary telephone wires are certain to be ruptured! An accident happens, and the miners are buried in a living tomb. But in a minute they connect their "Sharman" with the earth, and they are at once able to speak to the people above in the sunshine. They can describe their position, and give all the information necessary to guide the rescue party.

Then, again, the little wireless telephone of Mr. Sharman would be of general use to our Army and Navy. Scattered and fairly large bodies of moving troops can be kept under the instant control of their leader; and warships of all classes can be placed within reach of the actual voice of the Admiral of the Fleet. Water is easier to talk through than earth, and the electrical impulses travel downwards as well as along the surface of the sea. Thus a battleship can keep in very close touch with a submarine, and submarines can talk to each other. So, by the latest development of wireless telephony, there is now removed that awful isolation which made the submarine dangerous to work and limited in power.

Another remarkable and promising application of the principle of induction to wireless telephony is found in the Railophone—an invention of a Birmingham engineer, Mr. Hans von Kramer.

The Railway Telephone which May Make Collision Between Trains Impossible

From a train in rapid motion trails a short electric wire, about eighteen inches away from a wire fixed along the railway track. A current can be set up by talking into a telephone mouthpiece in the train; this current jumps, so to speak, the eighteen inches from the trailer to the fixed track wire, and carries speech with it. Or if a current is flowing over the fixed track wire, it affects the wire trailing from the train, and projects the message, as it were, into another train-telephone or into the general telephone system. It is expected that the Railophone, when perfected, will revolutionise the control of railway traffic and make collisions impossible.

The first telephone message into the skies was sent without wires at Cardiff in the autumn of 1911. An aerophone was used, the invention of Mr. H. Grindell Matthews. A flying-man fitted over his head a telephone receiver; and while rushing at almost a mile a minute through the air, he heard, above the roaring of the engine and the howling of the wind, a voice spoken into the mouthpiece of an instrument far below on the earth.

We hope in a future number of this work to be able to publish full details of the over-ocean system of wireless telephony which promises to link Britain and Europe to North America. If the final experiment is satisfactory, man will then be able to whisper a message across half the world.

TAPPING A SPRING DEEP DOWN IN THE EARTH

This wonderful photograph, taken by Mr. Coles Finch, at a Kentish waterworks, shows a spring of water that has been tapped down in the earth's crust. It is 260 feet below the ground, and from it a million and a half gallons of water are obtained every day.

A CITY'S WATER SUPPLY

How the Water Comes Down from the Hills and Up from the Springs to Every Town in the British Isles

WINE OF THE HILLS AT TWOPENCE A TON

STANDING on the flank of any extensive upland valley, broken at the sides by clefts or coombs, and containing a scattering of houses, one can see in a moment why each house was placed where it nestles cosily. If the valley be lofty and remote, yet inviting, the more important sites will have been occupied for many centuries, possibly previous to the compilation of Domesday Book. A glance shows that the early choice was made, and has been sustained, because perennial water passes near. Water, more than anything else, fixes the abode of man.

That was so even when he thought chiefly about defence in making his home refuge. The camp or fort must have water—preferably a spring that could not be diverted. It is so to-day. When men pitch a military camp, though but temporarily, their first considerations are those of the primitive man—dryness underfoot and water near by. Originally every house or small group of houses, had its own water.

Villages were built on brooks, or in the region of wells, and towns grew up on rivers, first to secure water, and then easy transit, and sometimes water-power. In lands where the population is nomadic, or migratory, the variations in water, in the rainfall or the wells, govern the movements of the community. Indeed, man must follow water, or he must arrange that the water shall follow him. During the early stages of his civilisation, when the conditions of his life were simple, he went to the water; now, with enormous labour, far-projected foresight, vast capital expense, and marvellous engineering skill, he gathers the rain from a hundred hills beyond the horizon, and distributes it inside the houses of a million people, so that a little child may turn a tap and drink. This is the story of that gathering and dispersal of the waters.

Looked at in detail, as it affects an individual man or a family, the question of amount in water-supply does not appear serious. A great engineer has pointed out that if it were possible to preserve from evaporation as much of the annual rainfall of London as could be caught by an upturned umbrella of full size, the year's accumulation would be enough to last one man for drinking purposes for a year. It would give him nearly three pints a day. Again, on the slated roof of a cottage giving an expanse of 500 square feet there would fall in Lincolnshire, at the low rate of 22 inches depth per year, enough rain to provide the family with 15½ gallons of water daily, an amount that probably is not exceeded in routine cottage life.

Though it may seem easy to collect these and larger quantities of water under rural conditions, the problem becomes greatly intensified when water must be made instantly available to huge and dense populations in cities for industrial and civic as well as domestic purposes.

For instance, the people of the London water-area, about seven millions in number, use 225,000,000 gallons every day, although their rate of consumption is not half as great as that of some foreign cities where water is far less in evidence before the public eye; but to supply 225,000,000 gallons per day a stream is needed running day and night, at the rate of two miles an hour, 30 feet wide and 12 feet deep. That is the present measure of London's need.

In ancient times the problem of water-supply for the great cities was a larger question than the supply to modern cities, because engineering power was less. As one approaches Rome the first signs of its antiquity and decay are observed in the gaunt ruins of mighty aqueducts which here and there bestride the drear Campagna.

Nine aqueducts were in use in Rome in the year A.D. 97, and two others were added later. They brought water into the city from distances varying between eleven and sixty-two miles. The greater part of these conduits was underground, but they emerged as they neared the city, and were carried on arches, as illustrated in the impressive ruins of the Aqua Claudia.

Our Water System of To-day in Use Two Thousand Years Ago

These aqueducts were chiefly constructed of bricks, stone, and concrete, though lead, bronze, and wooden pipes were used for the final distribution of the water to the houses and baths. The engineering was such as to allow of the use of gravitation as the power throughout, though the principle of the siphon was understood, and had been adopted in earlier ages by the Phœnicians. An unusual proportion of the Roman water-supply would be used for their baths, the bath being a sort of central institution in the social life of the city—club, library, restaurant, and place of amusement.

The treatment of the water was curiously similar to ours of to-day; that is, the supply was sent forward to service reservoirs, and was only finally distributed after it had passed through settling and filtering tanks. The remains of Roman-raised watercourses can be found in various parts of the Empire, the three-tier aqueduct at Nîmes, 160 feet high, known as the Pont du Gard, and the two-tier aqueduct of Segovia in Spain, being the most characteristic examples. The Roman treatment of the subject was typical of the great cities of antiquity; and Athens and Jerusalem still use a remnant of supplies that were probably engineered 2000 years ago.

The Unending Race Between the Population of Great Cities and Their Water-supply

Of all the departments into which public work divides naturally, none perhaps requires so much forethought and protracted expenditure before a remunerative return is made as the provision of a plentiful supply of good water for a great city. The increasing demand for water in a rapidly developing town is extraordinarily swift and inexorable, and there are towns which have had to go to Parliament for fresh powers twenty times in fifty years. No urban community is keeping pace with its public duties if it has not secured a water-supply that is sufficient to meet the growth of the next twenty years. That is recognised as an axiom by all who have studied the question of water-supply.

One reason for far-reaching preparation is the peculiar variability of rainfall and a consequent liability to destructive drought. On a gathering ground that is quite favourably situated the supply may sink in a dry year to only about 60 per cent. of the average supply of fifty years. Another reason is the impossibility of quickening the command of water to meet emergencies—the enterprise of securing a constant volume of water is comparable to a slow siege, deliberately planned, carefully laid out, skilfully timed.

The enormous cost of waterworks makes it imperative that successive additions should only be completed and be brought into use as they are needed, for a city can as little afford to have too much artificially gathered water as to have too little, since it pays for all it gathers, whether it uses it, leaves it, or wastes it. Hence water-supply is a question demanding far-flung thought; and the operations it entails illustrate the true use of capital perhaps more perfectly than any other municipal or national enterprise. Millions of money have often been sunk, in foresight and faith, before a farthing has been received in return.

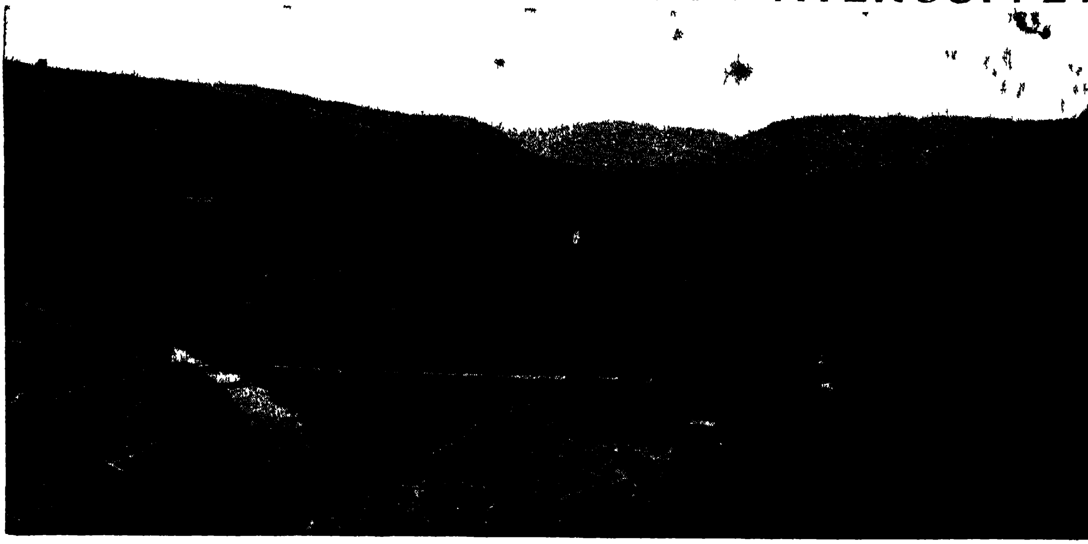
The Taint of the Shallow Well and the Earth-filtered Purity of the Deep Well

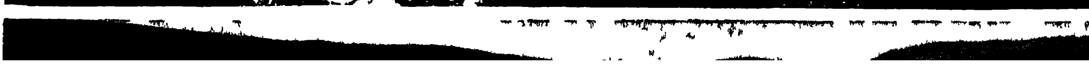
The three usual methods of procuring water are by the use of springs or the sinking of wells; by an intake from rivers; or by conveying from afar the waters of lakes, or damming up valleys and so forming artificial lakes or reservoirs in hilly or mountainous districts. Some towns have used all these methods at once, but as they reach a population of half a million or more they feel often that only the latter course can provide a permanent solution of their difficulties.

Spring or well water is the ordinary village supply, and is used in a supplementary way in many towns. Almost every large town has a history of its wells, which have been gradually superseded by a regular piped supply of assured purity. Thus as late as 1848 Glasgow was being partly served by seventeen wells, and the sites of twelve ancient wells are known in the now crowded parts of Sheffield.

Sooner or later surface wells are certain to become impure. A recent epidemic in Lincoln had one of its principal sources of origin in a well of great local repute for the supposed efficacy of its waters. Deeper wells are often sunk into the chalk, keuper or bunter strata, and tap an abundance of excellent water. An example is furnished by Nottingham, which has such a plentiful

THE SOURCE OF LIVERPOOL'S WATER SUPPLY





The top picture on the page shows the Vyrnwy Valley in Wales as it used to be Then a great dam nearly a quarter of a mile long, containing over seven million cubic feet of masonry and weighing 679,000 tons, was built across the valley as seen in the second picture This held up the River Vyrnwy, converting it into a great lake, the largest reservoir in Europe, containing 12,000 million gallons of water, running through pipes to Liverpool, nearly seventy miles away.

and impure pumped water that it is doubtful whether a mistake was not made when it sought a supplementary and much dearer supply from the head-waters of the River Derwent.

Water pumped from deep wells has to be stored in covered reservoirs, as under the light it scums over with a green vegetation, whereas the surface waters gathered from moorlands by gravitation into lakes and reservoirs remain free from such growths.

Wells that Leap to the Surface and are Never Exhausted

The supreme instance of service from wells is London, which receives nearly forty-three million gallons per day, or almost one-fifth of its whole supply, from the wells of some of the companies that were bought out by the Metropolitan Water Board. Under London itself indeed are notable wells, some of an artesian character, sunk into the chalk below the London clay.

Artesian wells, so called from Artois, the old province in Northern France known as Artesium, where such wells have long been used, are the upspring of water confined below an impermeable stratum, which, being bored through, gives the water its release, and it rises to find its natural level. The town of Spalding, in Lincolnshire, is supplied with five million gallons of water daily from one spring of this character at Bourne; while other springs in the same town, rising in what was the courtyard of the Castle of Hereward, flow away as a small river.

The likelihood of rivers becoming contaminated below their upper reaches is obvious, but there is an equal certainty that their waters can be purified for drinking. More than 80 per cent. of the water consumed in London, which is by far the most healthy great city of the world, is taken from the rivers Thames and Lea, as Paris is supplied from the Seine, Leeds from the Wharfe (in part), Aberdeen from the Dee, Cheltenham from the Severn (in part), Durham from the Wear, Norwich from the Wensum, Middlesbrough from the Tees, and York from the Ouse.

The Need of a National Water Board to Divide the Nation's Water-wealth

Waters for human consumption may be divided into those which are impure originally, but are cleansed and made innocuous, and those which have never been impure. Most of the river waters belong in some degree to the former class. First by storage and settlement such waters lose their bacteria largely, and then are made safe for use by filtration. Still, the ideal water-supply is that which has never been impure, and it usually has the further advantage that, descending from hilly regions, it can be stored at a great height in service reservoirs—at such a height, indeed, that, without pumping, the water will flow of itself to the loftiest storeys of the highest buildings in a city of varying altitudes.

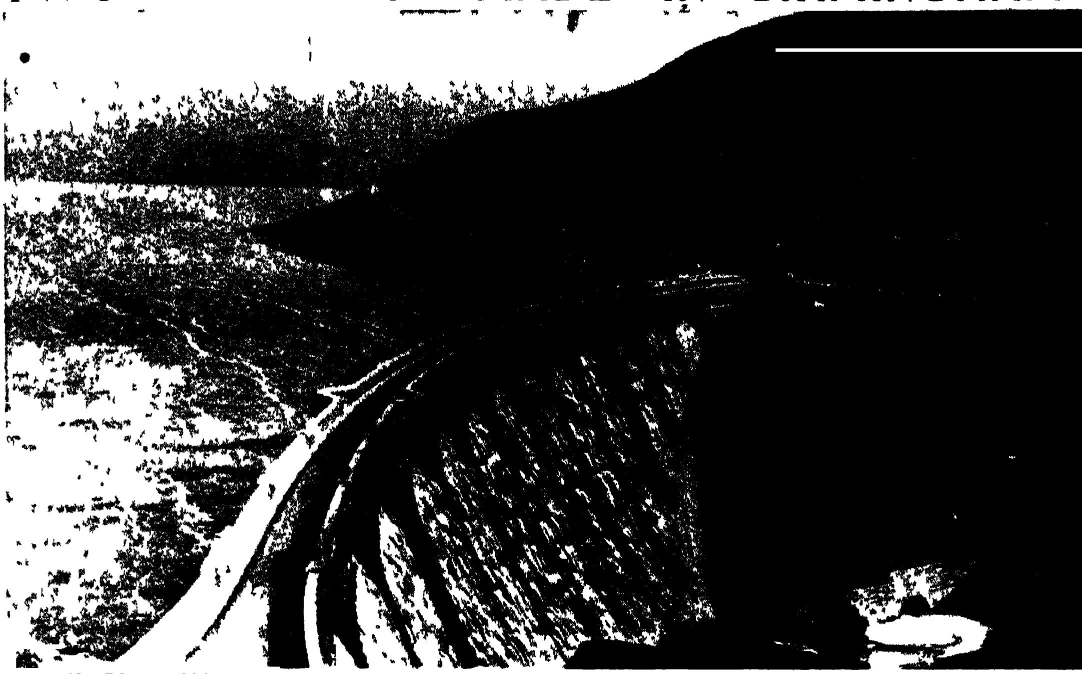
Undoubtedly a time will come when the great cities of our country will need the use of all the untainted lofty gathering grounds of water, and will be ready to compete for them with a vigorous expenditure of borrowed money. Then authority will have to be called on to make a division. At present there is a sort of promiscuous seizure, regulated only by the municipal purse and some very inadequate laws. What will be needed is a National Water Board apportioning the national water-supplies. Some approach towards this state of things has already been made under the pressure of circumstances.

The Custom of Dividing up the Hill-waters Among the People Towards whom They Flow

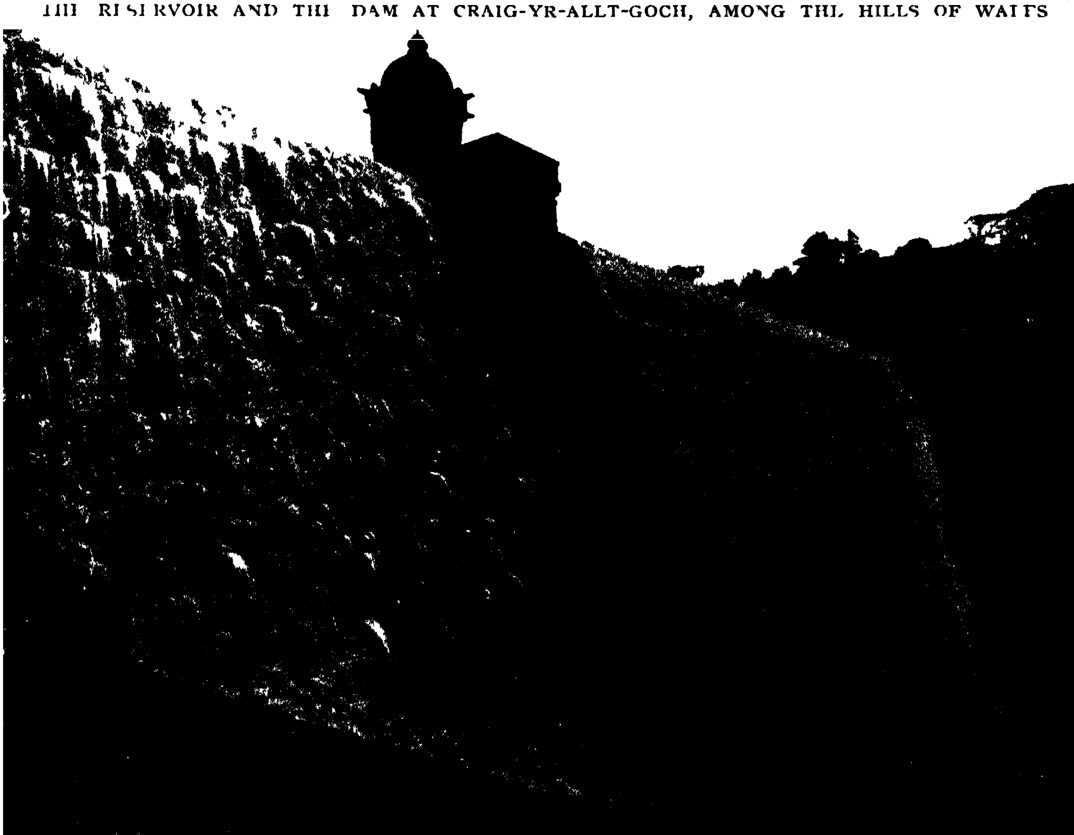
As early as 1860 Glasgow had begun to receive the waters of Loch Katrine, and in 1894 Manchester annexed the Cumbrian Lake Thirlmere. Liverpool went to the River Vyrnwy, in Mid Wales, and made a lake that came into formal use in 1892; and Birmingham, by 1904, had secured supplies from the Elan Valley, in Wales, by damming two stream-cut mountain valleys beyond the Wye. Bradford has gone for its supplies across two intervening river basins to the valley of the Upper Nidd; and even Sheffield, half-encircled by lofty moorlands and with six or seven streams meeting almost within the city boundaries, has been obliged to join with Nottingham, Leicester, and Derby to meet future needs by securing a share of the head-waters of the Derbyshire Derwent. The joint Water Board established to store and equitably distribute the waters of the Derwent is one of the first attempts, on the scale of a great watershed, to organise a complete storage with due regard to the claims of all who live between the mountain sources and the sea.

This plan of co-operation and friendly division is bound to be carried out with frequency in the future, and the sooner some national preservation and apportionment of the water-wealth of the hills is made the better. It can only be done by wide areas which contain considerable urban populations, and villages afflicted with drought taking joint action and dividing pro rata the cost of storage and main pipe-line

TWO NIAGARAS "MADE IN BIRMINGHAM"



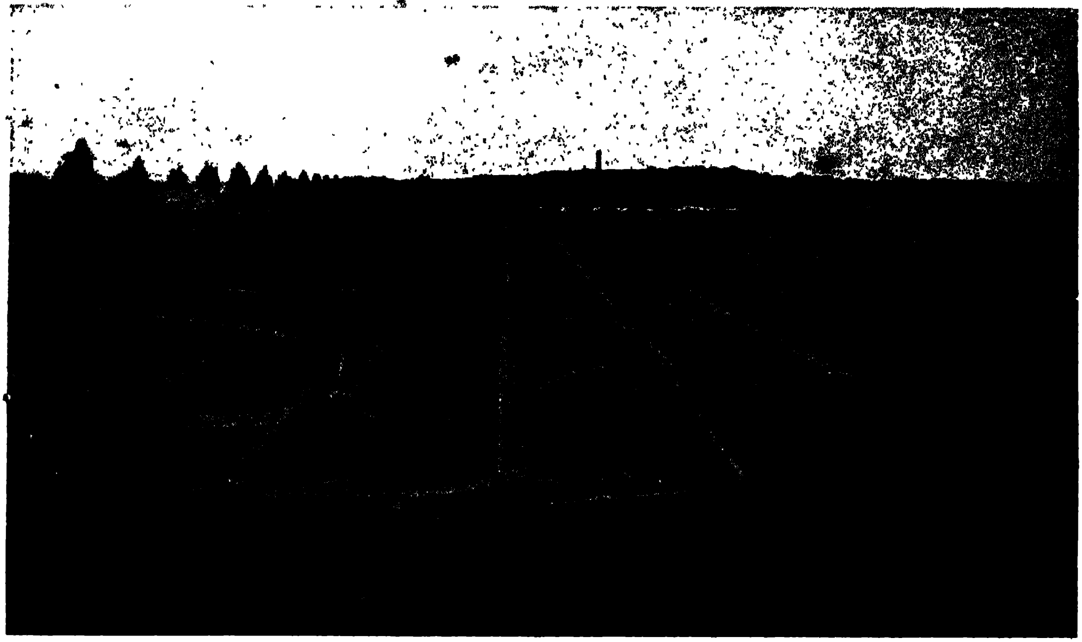
THE RESERVOIR AND THE DAM AT CRAIG-YR-ALLT-GOCH, AMONG THE HILLS OF WALES



THE NIAGARA-LIKE FALLS OVERFLOWING THE DAM AT PEN-Y-GAREG

These two imposing waterfalls, which may well be described as Niagaras made by man, are part of Birmingham's water-supply. Ultimately, Birmingham will be able to store up no less than 17,960 million gallons of water. At present she can store 11,320 million gallons. The falls of water seen in these pictures are really the overflow of surplus water, which escapes over the dam walls.

A RESERVOIR THAT COVERS TEN ACRES



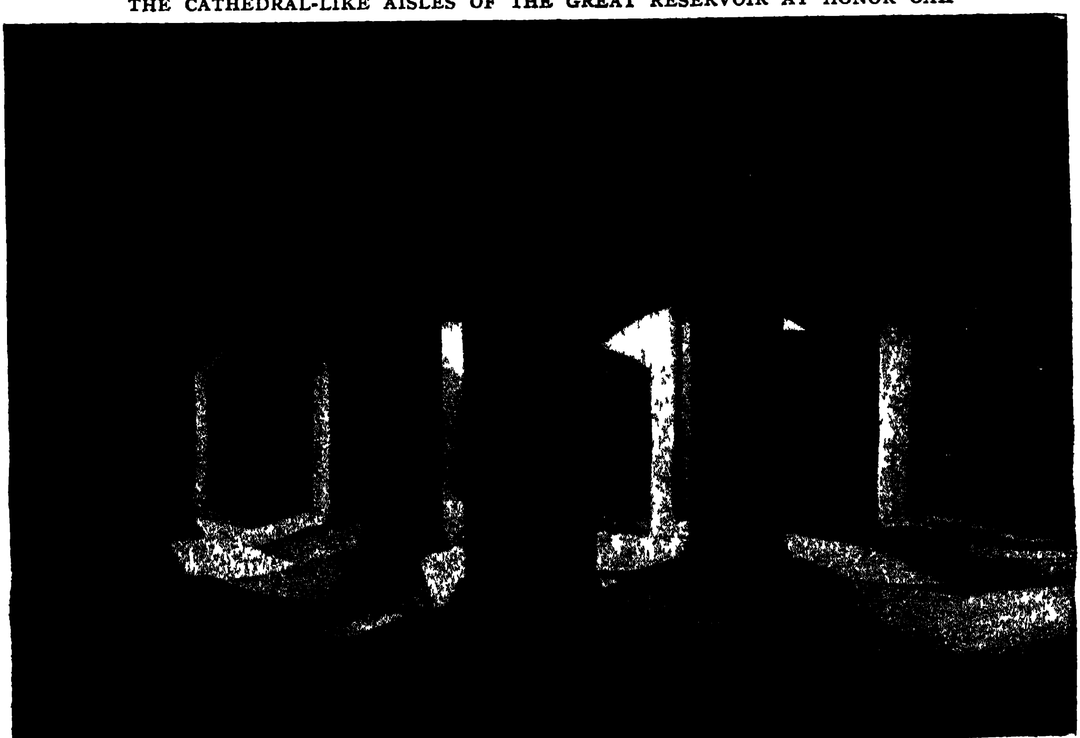
THE ARCHES SUPPORTING THE ROOF OF THE GREATEST COVERED RESERVOIR IN THE WORLD

THE LONG LINE OF ARCHED WALLS SUPPORTING LONDON'S TEN-ACRE RESERVOIR

Most of the London reservoirs are in the open air, but at Honor Oak there is a great covered reservoir, the largest of its kind in the world. It covers ten acres, and the roof stands on arches, as shown in these photographs, which were taken while the reservoir was being made. Altogether nineteen million bricks were used in building this immense storehouse of water for London.

THE SUBMERGED CATHEDRAL OF HONOR OAK

THE CATHEDRAL-LIKE AISLES OF THE GREAT RESERVOIR AT HONOR OAK



THE IMMENSE COLUMNS UPHOLDING THE ROOF OF THE HONOR OAK RESERVOIR

These fine views of the great Honor Oak reservoir may never be seen again; they were taken before the water was let in. The pictures show how closely this vast water-house resembles the cloisters of a cathedral. London uses a million tons of water a day, enough to make a river twenty feet wide from London to Birmingham; and a year's supply would make a deep lake four miles square, big enough to float all the battleships in the world.

distribution, while each area of water-users pays for its own local distribution. Those who wait longest will fare worst.

At present there is no scheme of national conservation, but legislative customs are being established for the dividing up of the hill-waters among the people to whom they would naturally flow. The legislative and legal views of water-gathering have been almost entirely confined hitherto to fixing what proportion of the water stored must be reserved for each town or district that makes a claim, and to determining how much compensation water must be sent down the bed of the stream daily, after the ordinary flow of water has been impounded.

The Basin of Water that Gains More as More is Taken

The amount let by for the use of those who dwell on the banks of the stream, mill-owners, manufacturers, and so on, varies according to the industries of the district, one-third of the total flow being the maximum compensation allowance. In any case the regulation of the water sent down the stream, its restriction, if need be, to hours when it can be properly utilised, and the attention given to the releasing of the flow of water from the saturated upper grounds into the beds of the streams that feed the reservoirs, tend to improve and equalise the ordinary supply, so that, beyond the storage of pure water for distant towns, there is an advantage to the people who dwell by the banks of the stream. The flow is improved for practical purposes, not injured, by the works which retain water. A judicious storage gives a more even supply, and less waste. This ought to be so, for from twenty to twenty-five per cent. of the outlay on waterworks is spent in providing compensation water.

How the Water-wealth of a Mountain Valley is Calculated

When a stretch of lofty and lonely moorland is coveted as a gathering ground for the water-supplies of a city the first question to be settled is how much water does it discharge normally into the streams that will fill the projected reservoirs. The calculation is far from simple. A single rain-gauge gives a record that cannot be relied on, for local position has a marked effect on the registration of a rainfall. An average should be taken of a number of gauges. Then the rain that falls is not an index, necessarily, to the amount of water that finds its way into the streams which feed the dams. The character of the soil must be considered. From some soils water flows off quickly and is lost in floods. Other soils become saturated like a sponge, and slowly give up their watery stores. Evaporation is swifter and more constant in one place than another. After long drought the earth is only slowly charged with moisture by percolation, though its thirst may be keen. The water-producing power of any locality varies enormously from time to time. Thus, a huge spongy mountain will discharge into the stream at its foot, at one part of the year, in a given period, 1500 times as much water as it will discharge during an equal period at another season. From this immensely variable output an average has to be obtained before the water-wealth awaiting the reservoir-maker can be calculated.

The enterprise of providing a gravitation water-supply to a city divides itself into three stages—the storage, the conveyance, and the distribution of the water. Usually the storage is artificial, but in a few cases it is natural with artificial additions, as in the use of Loch Katrine by Glasgow, and Lake Thirlmere by Manchester.

How Millions of Tons of Water are Held Up Safely in the Hills

In each of these instances a good deal of engineering was needed before the amount of storage would satisfy the immediate needs of the city concerned. Glasgow took over, in 1855, at a cost of three-quarters of a million, the companies that were supplying the city, and also began to prepare for tapping Loch Katrine to the amount of 50,000,000 gallons per day. The Act which allowed this provided that the waters of the loch should be raised four feet in depth, and that in summer it might be drawn on till it was three feet below the previous summer level. But thirty years later Glasgow was obliged to obtain permission in another Act to raise the level of the lake five feet more, and also to raise the neighbouring Loch Arklet twenty-five feet, and dam back its waters from their outlet into Loch Lomond, so as to turn them into Loch Katrine. In this way another 60,000,000 gallons a day were secured, while the necessary compensation waters were brought from Lochs Vennachar and Drunkie.

Perhaps the chief interest in water-storage enterprise is excited when huge masses of masonry have to be sunk deep into the earth and raised high above it to block valleys and bank in their waters, thus forming artificial lakes or a succession of reservoirs. Dams of this kind are either made with earthen embankments having a

CARRYING A RIVER ACROSS A RIVER

A BRIDGE OF PIPES THROUGH WHICH BIRMINGHAM'S WATER-SUPPLY PASSES

A CLOSE VIEW OF THE GREAT PIPES WHICH CARRY WATER FOR LONDON

The upper picture shows how water has occasionally to be carried in great pipes over a stream. In the bottom picture we see two water-mains before they are covered in with earth. The earth protects them from frost, but, if a pipe should burst, self-acting valves would at once stop the flow of water.

central core of puddled clay, or they are made of masonry. Sometimes in America earthwork is backed by timber, and there are instances of steel being used. Whether the embankment be of earth or of masonry, a deep trench down to a firm bottom is cut, and is puddled with clay so as to secure that there will be no percolation through the underlying strata. The bank is then usually built up with concrete in which blocks of stone are thickly embedded, and the wall above water is faced with stone.

The strength of the dam is made commensurate with the anticipated pressure of the water. Thus, the dam of the Vyrnwy Lake, in Wales, supplying Liverpool, holds 12,000 million gallons behind a wall 144 feet from foundation to overflow, across a width of 1172 feet. The dam in the Croton River, one of the reservoirs for New York, has a water pressure of 260 feet in depth. The Vyrnwy wall is 127 feet thick at its base, and its masonry has a weight of 510,000 tons. The area of the lake is 1121 acres. The dams, three in number, in the Elan Valley, Radnorshire, which supply Birmingham, will have almost an equal storage capacity, and in course of time will be supplemented by two more reservoirs in the Claerwen Valley, with a third at the junction of that valley with the Elan. Bradford finds a storage of over 2500 million gallons in the valley of the Upper Nidd; and Sheffield, with moorland at its doors, has completed or projected storage for 7357 million gallons, apart from the Derwent supply shared with Nottingham, Derby, and Leicester.

The Way to Freedom for the Rushing Storm-waters

A feature of all dams is the provision for overflow, as from time to time enormous amounts of surplus water must pass the containing wall. This is usually arranged for by a waste weir or by-wash at the end of the wall, the water falling over a series of steps to break its force, before it escapes by the lower course of the stream.

As the flow goes over the sill at the lowest point in the embankment, it is mechanically measured. In the case of Lake Vyrnwy, a large part of the length of the containing wall may be used as a by-wash. The ordinary overflow there occupies a width of 456 feet, but at a higher level a further overflow of 288 feet becomes available. In the case of the Birmingham works in the Elan Valley, the discharged compensation water is used to generate power by the action of turbines. A rule for the safe release of storm-waters is that the sill by which they escape must be fifty feet long for every thousand acres drained.

Failures to observe the scientific principles of stability, or to allow a sufficient overflow, have led to terrible devastating bursts in many countries, especially, though not exclusively, in the case of earthen embankments.

The Awful Night when the Waters Washed Away the Great Dam at Sheffield

The most thrilling catastrophe of the kind in this country occurred on March 11, 1864, when the Dale Dyke reservoir, in the Loxley Valley, one of a series of dams supplying Sheffield, burst with appalling consequences. The dam, about six and a half miles from Sheffield, was 450 feet above the entrance to the town. It contained about three million tons of water. A landslip dislocated the embankment, and in a few minutes about 700 million gallons of water were rushing through the narrow valley at midnight on the sleeping town, at the rate of a mile a minute, and sweeping everything before them till the opening out of the valley allowed the waters to spread. The number of lives lost was 244, and so much property was destroyed that the water company paid as compensation £373,000. The warning of that awful night has never been disregarded in England by engineers of water-works.

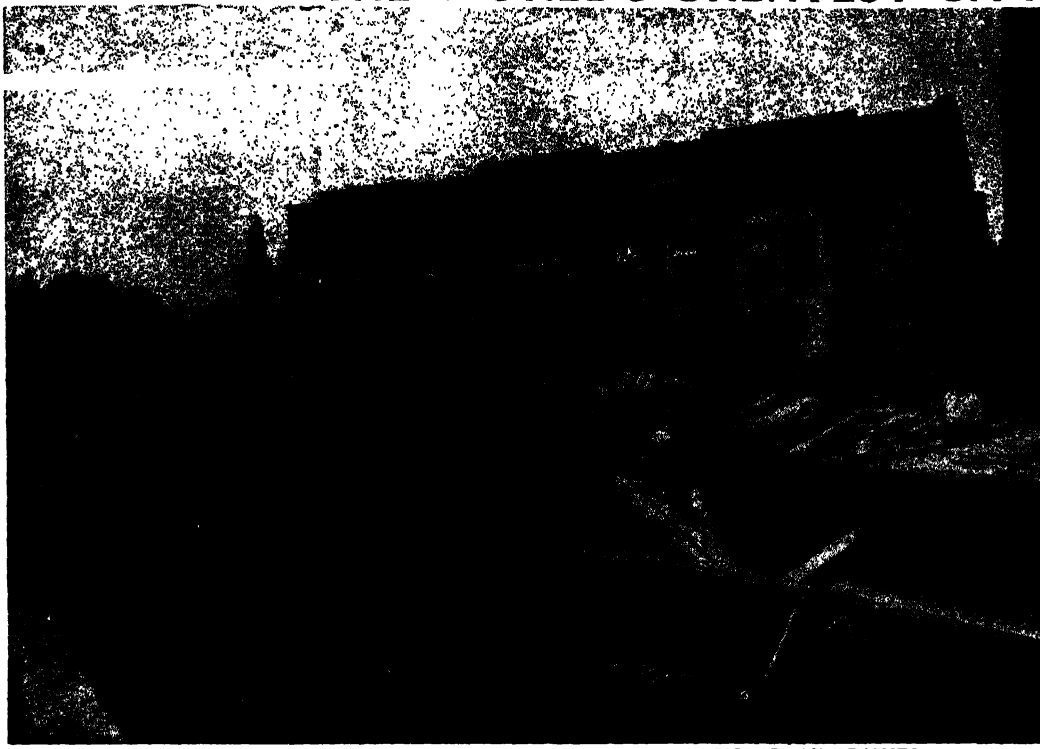
The customary method of drawing off water for consumption is by means of a valve tower. The tower is a dry well built into the reservoir, and carrying in an outer circle pipes controlled by valves through which the water can be drawn off at various levels, and turned into the supply aqueduct. The object is to use the purest and clearest water according to the amount which the reservoir contains, and that will be neither the upper nor the lower layers.

The Hungry Water that Slakes its Craving with Chalk and then Refuses Lead

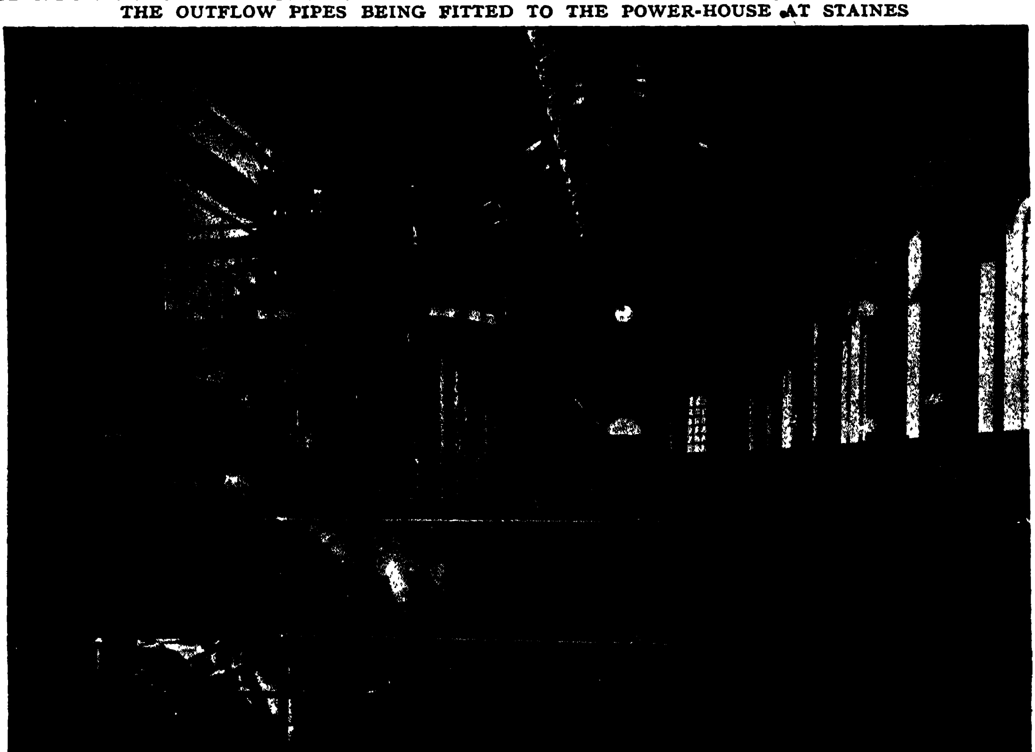
The height of the storage reservoir is a matter of importance. If it is great, the fall to the distant town may be broken by intermediate distribution reservoirs to take off the "head" or pressure on the pipes, and to arrange for distribution to different heights any place that is being served. Thus the waters are let down from reservoir to reservoir, a fresh start being made from each stage, and pressure diminished.

The Loch Arklet supply of Glasgow comes from a height of 480 feet; Thirlmere sends down water to Manchester from 533 feet, but the older supply to the city, from the

WATER FOR THE WORLD'S GREATEST CITY



THE OUTFLOW PIPES BEING FITTED TO THE POWER-HOUSE AT STAINES

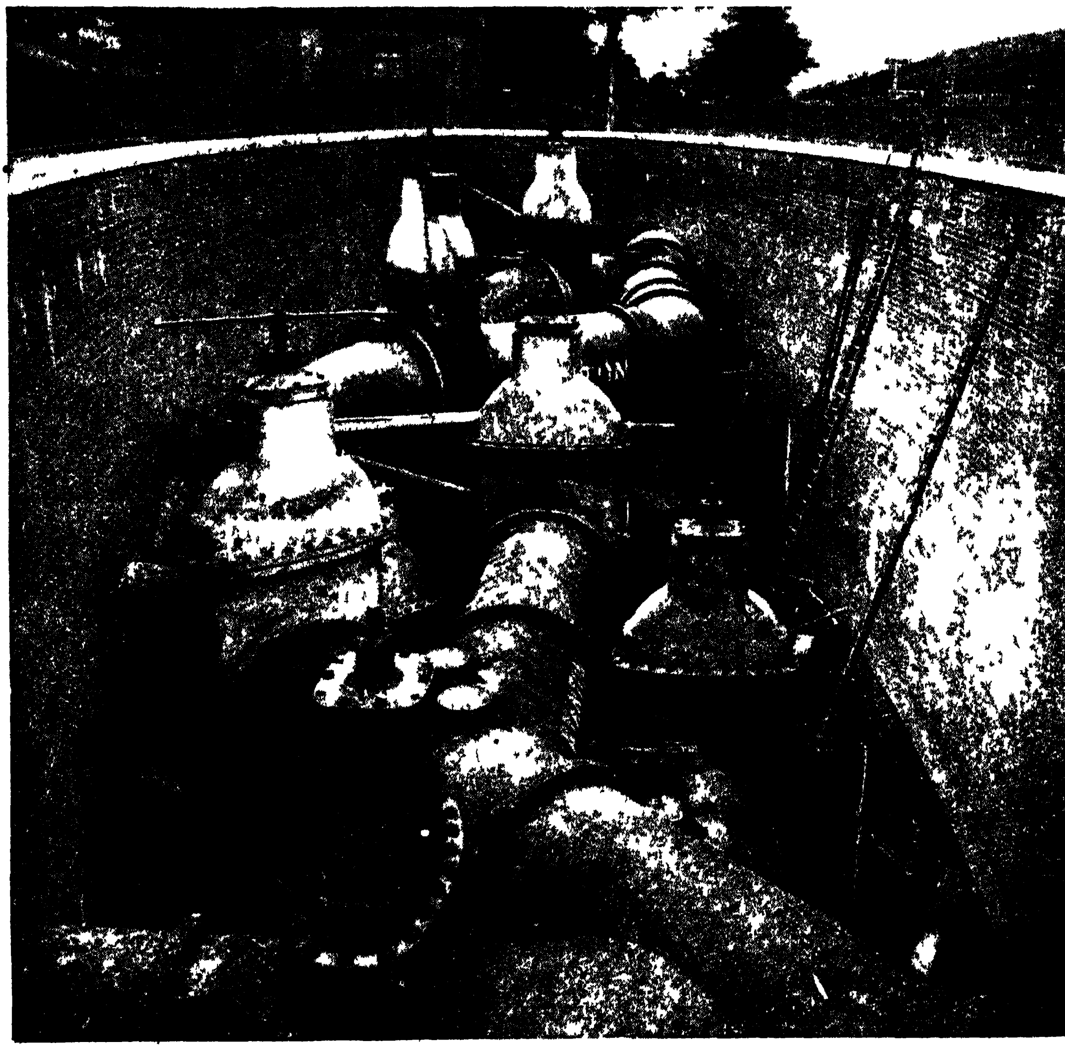


INTERIOR OF THE POWER-HOUSE AT WALTON, SHOWING THE PUMPING ENGINES

London draws more than half its water from the Thames The water is run into large reservoirs, where it stands long enough to allow impurities to settle. Then it is pumped by engines like those shown in the bottom picture, through pipes similar to those above, into other reservoirs, where it is filtered.

Woodhead reservoir in Longdendale, came from a height of 777 feet, Vyrnwy starts the Liverpool water from 825 feet. Birmingham's Foel valve tower is 782 feet above sea-level, but the top water-level of the Craig-yr-Allt-Goch reservoir in the Elan Valley is 1040 feet, and the Pant-y-Beddau reservoir in the Claerwen Valley will be 1175 feet. The Upper Redmires dam, which gives Sheffield its high-level supply, is about the same height (1170 feet), and the highest of the storage reservoirs of the great English towns is the Angram reservoir of the Bradford Corporation on the Upper Nidd, at 1187 feet. Not only, then, do these cities receive a pure water, but their gravitati[illegible]ply can be used effectively at varying heights without expenditure in pumping it up to secure a "head."

The water-supply of a great city having been stored for consumption, some means must be adopted, usually before it starts on its long journey to its destination, to clarify and, if need be, purify it. While moorland waters are usually soft and pure they are liable to discoloration and some times have a "thirst" for mineral ingredients which causes them to absorb lead from new pipes and so become deleterious.



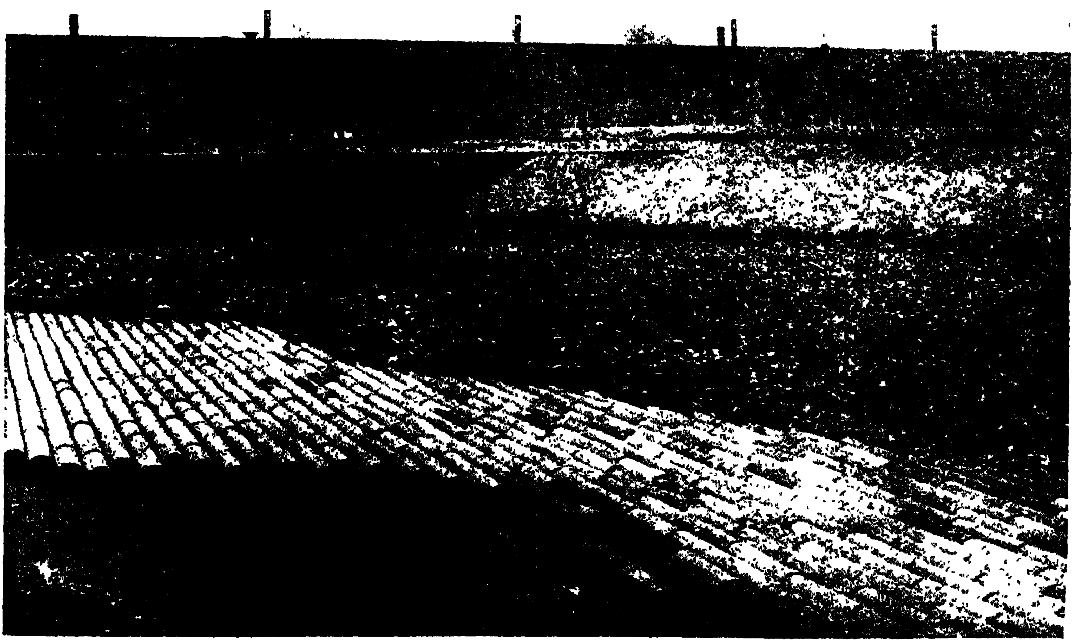
THE VALVE PIT AT A LONDON RESERVOIR

All the reservoirs round London are connected, so that a shortage in one district can be made up from another. Each reservoir has a elaborate system of valves to regulate the supply, and this picture shows how powerful these valves are

The most notable illustration of this danger occurred before 1886 in Sheffield when lead-poisoning was traced to the highest and purest water-supply from the Redmires dams. Quite similar water from

FILTER-BEDS FOR THE WATER OF LONDON

A GREAT FILTER-BED READY TO BE FILLED AT HAMPTON COURT



THE THREE DEPTHS OF LOOSE PIPES, GRAVEL AND SAND, WHICH MAKE UP A FILTER-BED

Proper filtering is a most important factor in a city's water supply, for it is now known that the filter of gravel and sand stops not only solid impurities, which can be seen, but also many dangerous microbes. The upper picture shows one of London's great filters at work, and the lower picture shows a filter-bed in course of construction. The filters are cleansed every few weeks.

the Loxley Valley was found to be innocuous. The Loxley water, however, came through a bricked and mortared tunnel two miles long, and had an opportunity of taking up the chemical ingredients it lacked. The Redmires water was then treated with finely powdered chalk as it passed out of the dam, the amount of chalk varying with the state of the water, at a cost of a penny per 25,000 gallons, and no case of lead-poisoning has since been traced to this source.

Brown, Pure Waters that are Filtered to Look Clear

Similar treatment is found necessary and effectual with the Birmingham water drawn from the peaty heights around the Elan River. The soft waters that may attack new lead—old lead pipes become coated with a salt which resists water—are particularly suitable for use in manufacturing cities, as their corrosive action on boilers is exceedingly small. Railway companies water their engines as far as possible from such supplies.

Filtration is now regarded as necessary in the case of all surface water-supplies. In some cases—as with the river water—it is essential to the securing of purity. With the purest mountain streams filtration is advisable in order to combat discoloration, and also because unfiltered water may cause growths on the interior of the iron pipes which carry it on its journey townward, and these growths greatly impede and diminish the flow. The stages of filtration are varied by the condition of the water. Often it is passed through a fine copper gauze strainer of about forty threads to the inch. Then it is allowed to stand, in sedimentation tanks, until its rougher suspended matter has subsided. After this it is drawn, or pumped, off, and passed through the filter-beds. Such a bed consists of a lower layer of rough stone or brick ends, with rough shingle over it, and gravel over that, topped by several feet of sand.

The Long Journey from the Reservoirs in the Hills to the Water-Tap

Bacterial filtration through sand only becomes effective when a film of mud and microbes has been formed on the sand. After a time, however, the sand becomes clogged and impervious, and then a layer of it is removed and washed ready for further use. By a repetition of sand filtration contaminated waters may be made quite pure. In the case of mountain supplies, the filtration process is required rather for the sake of appearance than of purity.

The conveyance of the purified water from its source to its destination is often more expensive than the impounding of the supply. In the case of the Manchester supply from Thirlmere, the cost of the piping was ninety per cent. of the whole, the distance traversed being 96 miles. New York, which prides itself on using daily one-fifteenth of the amount of water which on the average goes over Niagara daily, is bringing a new service from the Catskill Mountains, a distance of 92 miles, at a cost of £30,000,000. The Vyrnwy Lake is 68 miles from Liverpool; Lake Katrine 35 miles from Glasgow; the Elan Valley outlet 74 miles from Birmingham; the Derwent dam 60 miles from Leicester; and the Nidd works 32 miles from the Chellow Heights service reservoir in Bradford. How are the waters conveyed these vast distances?

The aim of the engineers is to make from source to finish—from the water-tower outlet in the gathering reservoir to the distribution reservoir in the city concerned—an underground river with a gentle gradient, along a cement-lined passage, as near the surface as the contour of the country will allow.

Gentle Gliding Through Tunnelled Hills and Switchback Piping Under Valleys

For this purpose a careful survey is made. But often the rise and fall of the surface will not allow a graded river inside the earth to keep just sufficiently below the soil to avoid frost and downward pressure. When there is a rise of intervening hills above the height of the water-line a tunnel must be made. Thus Thirlmere Lake lies 250 feet below the summit of the Dunmail Raise pass across which the water for Manchester must travel, and so eight miles out of the first thirteen along the Manchester water-line are tunnelled.

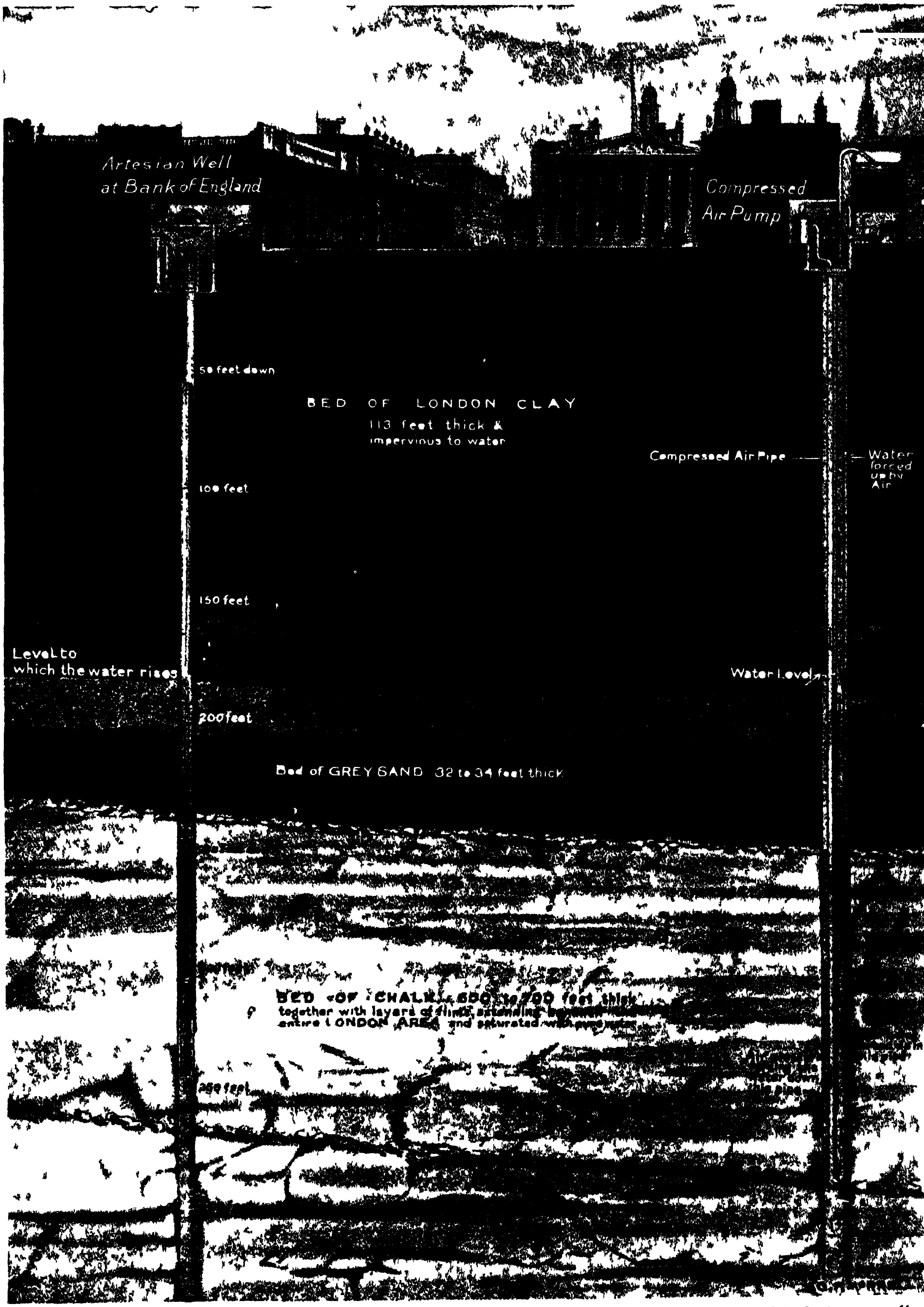
Again, where valleys are crossed at a lower level than the water-line, the water must be carried in pipes so as to siphon it down and up again to its former level by natural pressure, and tunnelling may be necessary, as, for example, where the Vyrnwy to Liverpool supply passes under the River Mersey between Runcorn and Warrington. Where pressure from a head of water is not required, and the ground will permit, the water is carried in an aqueduct or conduit lined often with blue brick, and sometimes concreted to resist subsidence or weight from above.

The simplest method of transit is by "cut and cover" and conduit. A trench is cut and a culvert built in it of the necessary

THE IRON BANKS OF PENT-UP RIVERS

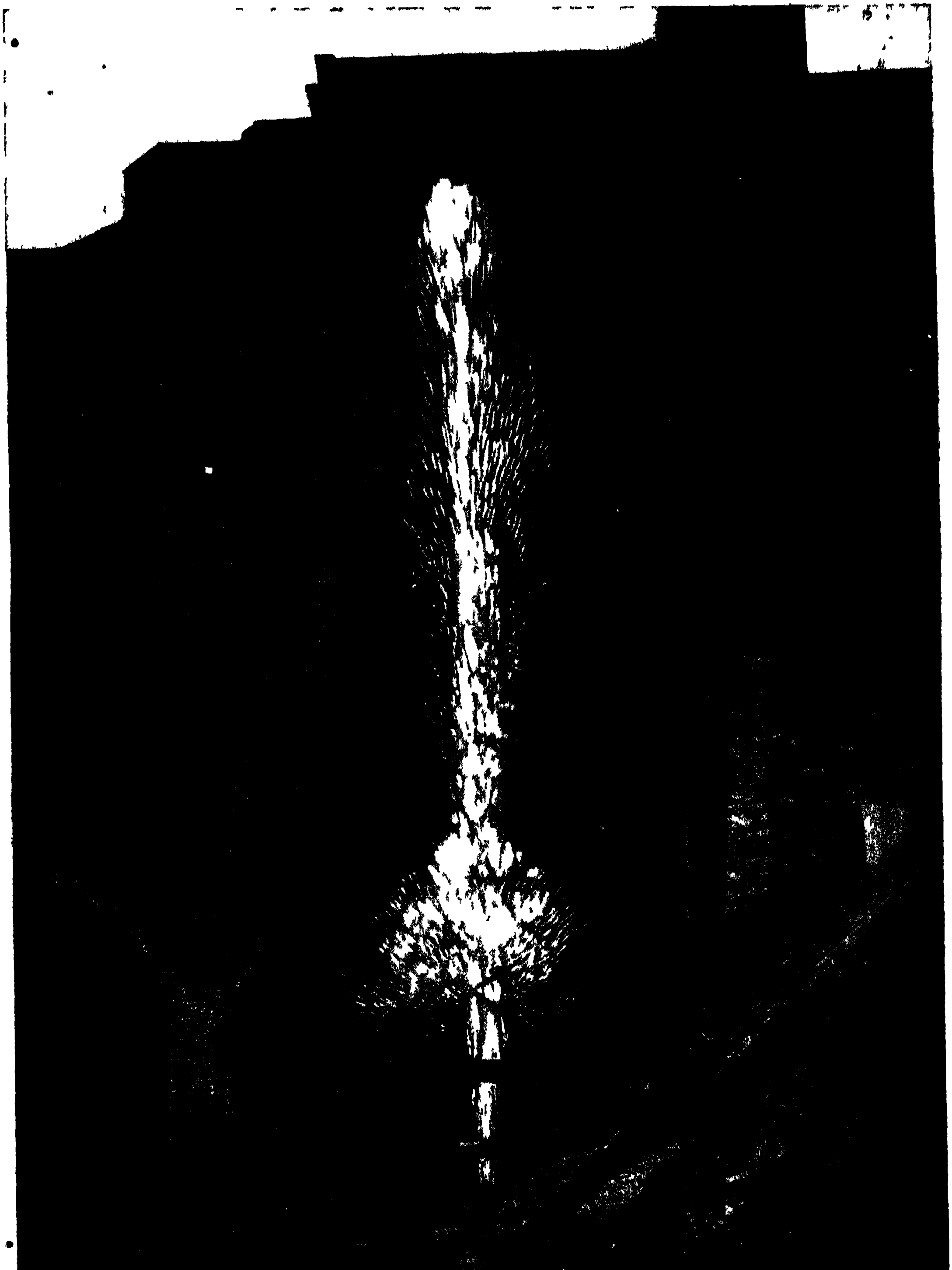
These men are laying the iron pipes which carry the water from the reservoirs to the streets and houses. If all the iron and lead water-pipes used in London alone were joined together they would more than reach round the world. Yet London's water-supply was more than equalled in the days of ancient Rome, where the yearly supply was nearly 40,000 million gallons more than London's is now, but this is accounted for by the enormous baths which were one of the features of life in the Eternal City.

THE ARTESIAN WELL AT THE BANK OF ENGLAND



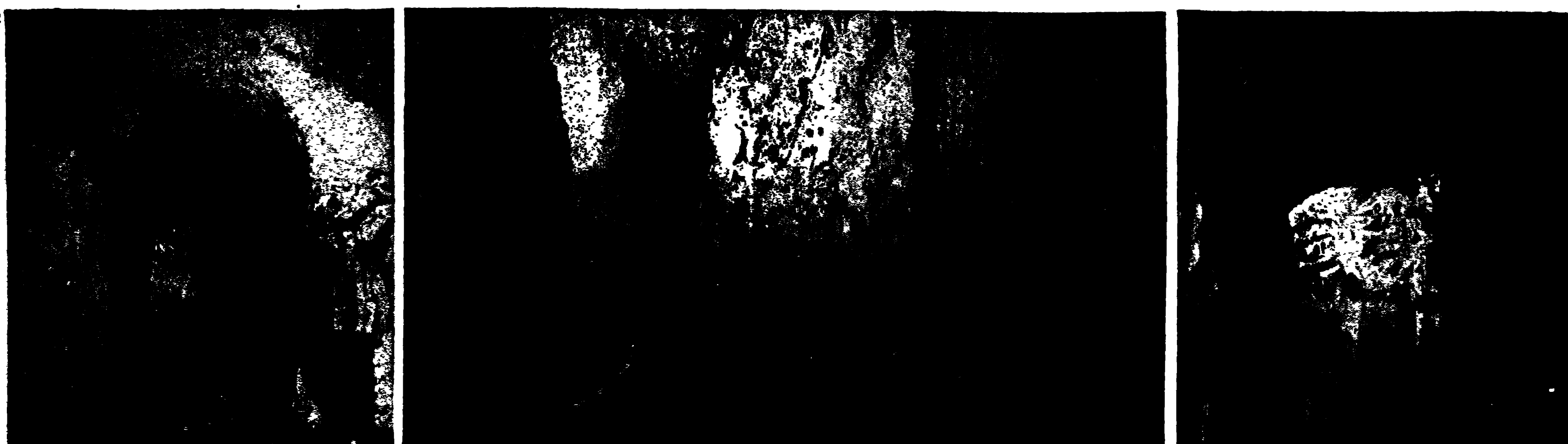
London gets nearly a fifth of its water from artesian wells one Essex well has yielded three million gallons a day. The one on the left is worked by suction while that on the right works by air pressure This well has two pipes connected at the bottom by a U shaped bend The water in the bed of chalk gets into these pipes, and compressed air, forced down one pipe, drives the water up the other

THE FORCE OF A NATURAL SPRING



This photograph shows the force with which water issues from the earth. Water can only be drawn from chalk when it accumulates in holes and fissures. To increase the yield of a well, therefore, it is the practice to explode a charge down in the bore-hole, and thus to cause fissures artificially, as is being done here. The artesian well is not a new idea; the Egyptians and the Chinese sank them thousands of years ago. The deepest artesian well is in America, and goes down about a mile.

THE NATURAL WATER-BED THAT LIES BENEATH THE GREATEST CITY IN THE WORLD



The fall of a single inch of rain over one square mile yields 14½ million gallons. The chalk under London holds this water like a sponge, but there are many natural holes, or fissures, in the chalk beds, such as are shown in the three lower pictures. Here the water collects, and it is this water that is tapped by wells.

The photographs on these pages are reproduced by courtesy of the Metropolitan Water Board, the Artesian Well Company, Messrs. J. Mansergh and Sons, T. Piggott and Co., Coles Finch, and J. Maclardy.

size, the top being, because of frost, not less than thirty inches below the surface when the conduit has been finished and the earth again filled in.

Chambers reaching the surface for ingress to the conduits are built at intervals. Where cast-iron pipes must be used, they are generally of about 42 inches in diameter. The Manchester-Thirlmere pipes are $1\frac{3}{8}$ inches thick, and are tested to resist a pressure of 180 pounds to the square inch. They are dipped in pitch and oil to resist corrosion. Cut-off valves are arranged to stop the flow in case of bursts, and valves are placed in the lower portions of piped depressions to empty the pipes on occasion and remove sediment. Where there is a bend in a pipe-line the pressure is great, and the pipe is "anchored" to keep it firm in its place. The pipes are socketed into each other, and the joints packed with yarn and lead. They carry the water from one "balancing" reservoir or tank to another at a corresponding elevation. Easements of land are bought, and arrangements made for laying several lines of pipes—three in the case of Liverpool, and five in the case of Birmingham—but the heavy capital expense of laying a line of pipes is always delayed until the demand is such that the additional supply of water can be quickly utilised.

The Water Used Every Day by the People of London, and the Cost of It

The water conveyed by conduit or pipe, part of the way by one method and part of the way by the other, from reservoir to reservoir, so as to preserve the properly graded fall when it reaches the service reservoirs near its final destination at such a height as will allow it to be distributed to the topmost floors of the highest buildings, is ready to enter at once the mains of the city. Thus Prescot reservoir receives for distribution the Liverpool supply; Mugdock and Craigmaddie the Glasgow supply; the Prestwich reservoir the Manchester service from Thirlmere; Frankley reservoir the Birmingham Welsh water; and Chellow Heights the influx for Bradford from the Nidd.

The Metropolitan Water Board, which since the Act of 1902 has taken over the works of eight metropolitan water companies and the urban districts of Tottenham and Enfield, supplies seven million people with water, over an area of about 550 square miles. The sum paid for these undertakings was nearly forty-nine million pounds. The Board has an income of over £$2\frac{3}{4}$ millions per annum, but is falling into debt. It has, or is arranging, a storage of twelve thousand millions of gallons, with a daily supply of 280 million gallons, which will give thirty-five gallons per person per day to a population of eight millions.

The supply of water to urban populations is either intermittent or constant—that is, the water is either only available during certain hours or is always "on," night and day. The constant supply is the only efficient and healthy service, an intermittent supply raising questions of cleanliness as well as of convenience.

The Water that a City Needs and the Water that It Usually Wastes

There is no doubt that a great deal of expensively gathered and distributed water runs to waste. In some American and Continental cities from seventy to ninety gallons per head per day are expended, chiefly probably in waste. A well-organised system should not show an expenditure of over 25 gallons per head per day, even where there is an abundant use for public baths, civic purposes, such as street cleansing, and for manufacturing processes. Probably any expenditure above 20 gallons per day per head is waste. Wise prevision by public authorities will enable the demands of the public to be met with amazing cheapness. Though Sheffield, for example, has spent over $3\frac{1}{2}$ millions sterling on waterworks, it is supplying its inhabitants with an abundant supply at less than *twopence per ton*.

It may be taken as an average that the capital cost of a great city's water-supply is from £7 to £10 per head of the population. For this amount the waters from the rain-swept hills, above the abodes of man, are banked up in reservoirs by walls of concrete which sink as deep into the earth as they rise above it, are decanted from their purest layers into cleansing beds of sand, while the surplus stores wash over the embankment and supply the mills down-stream.

The Arm that Holds the Drinking-cup a Hundred Miles Away

Now down dale, now up hill, seeking its level, the water is brought on its way, flowing, or by siphon pressure, to a reservoir above the town it serves, and thence is distributed through a meshwork of mains and piping to every house, and in some houses to every room for instant use. The long arm of municipal enterprise enables the town-cooped citizen to hold out his drinking-cup a hundred miles away for the pure distillations of the hills, and at such a cost that the price of the draught can only be expressed in fractions of the smallest coin.

THE INCREDIBLE NATIONAL WEALTH AWAITING DEVELOPMENT IN CHINA

China, now awaking to her opportunities as the most numerous nation on the earth, has enormous deposits of coal and iron, and it is quite probable that she may be the richest country in both these commodities. Seventy miles below Hankow, the city set on fire in the recent revolution, there exists one of the richest iron-mines in the world, where the ore exposed on the surface is estimated at five hundred million tons. The exploitation of this vast natural wealth, as by the enormous Hunyang Iron and Steel Works at Hankow, shown in this photograph, may lead to a great industrial transformation in the Far East.

THE INDUSTRIAL FUTURE

A Survey of the Lesser Nations and the Resources of Coal Power which will Determine Their Position

HOW COAL MAY TRANSFORM THE WORLD

Our survey of the great world of work has shown us three great industrial and commercial Powers standing out with an almost incredible domination resulting from the application and development of native power supplies by gifted white races. We have also seen that the world's resources are not as yet by any means fully developed, and that there is the possibility of great changes, both in regard to relative production in known power areas, and the commercial utilisation of powers and resources yet dormant. The world as it is demands our first attention, however; and we pass from the world's industrial leaders to the many nations, great and small, which, either because they do not possess in amplitude the means of carrying on large-scale machine industry, or because their peoples are either not gifted in the arts or are not developed in them, are less industrialised than Britain, America, and Germany, and relatively more engaged in agricultural pursuits.

It would, of course, be a profound error to value lightly the work done by a nation which is unable, for reasons that it cannot control, to build up industrial centres filled with the smoking factory chimneys which, a generation ago, a great French statesman coveted for the unpolluted skies of France. The development of coal-power by a nation fortunate enough to possess it spells what has been termed the "Industrial Revolution," and industrial revolutions are fraught with terrible dangers to a people. Machine industry concentrates the population in towns which, without the application of almost superhuman foresight, may easily become areas of social and physical degradation "where wealth accumulates and men decay."

The United Kingdom, the first nation to develop machine industry, has suffered sorely in this respect, as all pioneers must suffer. Both Germany and America, although developing later, and with the experience of the United Kingdom to guide and warn them, have by no means wholly escaped the consequences which arise from the rapid and little regulated growth of industrial centres. We can only note these things in passing here, for they will receive full treatment in another section of this work, but the close connection of economic and social science at this point should be fully appreciated. Commerce is a mighty branch of the activities of man, and to be scientifically regarded as part of what Pope termed the proper study of mankind—Man. Regarding trade as an instrument for the building of men, and not merely for the distribution of wealth as defined as commodities having value in exchange, we realise the close connection of industry and commerce with hygiene and sociology.

On page 743 is a clear statement showing the present relative position of the world's power producers, great and small. It will be seen that the contrast which obtains between the major and the minor coal producers is a very striking one. It must be insisted, however, that this test by present production is conclusive as to the future in the case of European nations alone. We see Austria-Hungary, France, Russia, and little Belgium heading the list of the minor coal nations. They do so, however, mainly because they are white nations, possessing a high degree of civilisation, which have developed such power resources as they possess. It does not follow, because these nations occupy such a high position as compared with those that follow them in the list, or as compared with the daughter nations of the United Kingdom, that the figures of present production by any means represent in their proper proportions the *potential* powers of the various contributors

to the grand total of nearly 1100 million tons of coal produced yearly by all the world. We shall see, as we proceed, that nothing in this world is more certain than that Asia will be as great as, and perhaps much greater than, Europe as a natural power area in the time to come. It is a certainty which raises many considerations, political as well as industrial and commercial, of the highest importance to Europe and to the world at large.

The Coal Power Resources of Austria and Hungary

Turning our attention first to the nations of Europe, we examined in the last chapter the power resources of the United Kingdom and the German Empire, and saw that Germany's coal is probably greater in extent, although inferior in situation, to that which we possess. We proceed to consider the great nation which heads the list of minor coal producers—Austria-Hungary, whose enormous territories have been recently enlarged by the annexation of Bosnia and Herzegovina.

Although Austria-Hungary leads France, Russia, and Belgium among European coal producers, her production is not so great as Belgium's in the power value of coal, because it consists as to more than two-thirds of brown coal, or lignite, which is greatly inferior to coal in heating value. Nevertheless, the Austrian and Hungarian power resources are very extensive, and have been much increased by the annexation of Bosnia. According to the evidence given to the Royal Commission on Coal Supplies by Mr. Bennett Brough, the Austrian deposits extend from Pilsen, on the Bavarian frontier, to Galicia, on the Russian frontier. The most important of the Austrian coalfields is that of Ostrau-Karwin, which is really a part of the great Silesian field chiefly possessed by Germany, and extending as far as Russia.

The Rich Seams of Austria-Hungary and the Coalfields of France

The Ostrau-Karwin deposits consist of over three hundred seams, ranging from eighteen inches up to twelve feet in thickness, of which over a hundred are commercially available. The Austrian lignite mines are also of great magnitude. On the slopes of the Erzgebirge there is a bed of fine hard lignite forty to fifty-three feet in thickness. Hungary has not a great deal of bituminous coal, but her lignite mines are valuable and productive. Bosnia produces a great deal of good lignite, and has some seams thirty to fifty feet thick. Altogether, the Austro-Hungarian Empire has a coal area about one-sixth as great as that of the United Kingdom, but her inferior coal resources are supplemented by water-power.

France is, after Germany, the greatest bituminous coal producer in the world, and has valuable deposits which, combined with recent development of her water-powers, make her, in point of present power utilisation, the fourth great industrial nation. Coal of commercial value is found in the north, in the centre, and in the south of France, and there are also some valuable deposits of lignite. The national production has not advanced very rapidly. As long ago as 1890, about 26,000,000 tons were produced, and after twenty years' further development the total is but 10,000,000 tons higher. The most valuable coalfield is that of the north, where the seams are continuous with those of Belgium. Actually great, but relatively small, France as a power area suffers by comparison with Germany; and the comparative advance of Germany in recent years is, of course, very largely accounted for by the French handicap in this supreme natural advantage. It is a point in the comparison which is easily overlooked, in spite of, perhaps because of, its overwhelming importance.

The Small Output of the Enormous Coal-fields of Russia

A minor point to be borne in mind when comparing the fuel of France with that of, say, England is that France, for climatic reasons, does not need to spend so much strength or income in the getting of coal for the purposes of domestic heating. This somewhat improves her comparative position, but it does not atone to her for her comparative lack of native power.

Russia comes next under review. The enormous territory of Russia in Europe includes some great coal areas, larger indeed than those of the United Kingdom, but not nearly as valuable. Thus, the Donetz coalfield alone has an extent almost as great as that of all the coalfields of the United Kingdom, but not only are the seams thin but the coal is poor in quality. The Moscow coalfield, again, has an area of 9000 square miles, but many of its thin seams are too deep to be commercially valuable, and they are therefore not worked. We need not be surprised, therefore, if Russia, in spite of her enormous coalfields, produces but some 25,000,000 tons of coal a year, and that in recent years her output has been almost stationary at about that figure. The facts in this case

are another reminder of the importance of possessing not merely coal, but easily won coal; and it cannot too clearly be remembered that in the world of commercial competition *coal which cannot be competitively worked does not, for practical purposes, exist at all.* Not content with the existing economic position, the Russian Government is actively taking steps to develop water-power in districts such as the Caucasus. Great power-stations are to be erected to supply cheap current to be the life-blood of factories and workshops.

POWER PRODUCERS—GREAT AND SMALL

The figures are for 1907, which was a year of world-wide good trade.

NATIONS	Tons of Coal Produced	Per Cent. of World's Output
THREE CHIEF INDUSTRIAL POWERS—		
United Kingdom ..	268,000,000	
United States.. ..	429,000,000	
German Empire ..	202,000,000	
	899,000,000	82·1
MINOR COAL PRODUCERS		
Austria-Hungary ..	47,000,000	
France	36,000,000	
Russia	25,000,000	
Belgium	23,000,000	
Japan	13,000,000	
China	8,000,000	
Spain	4,000,000	
Chile	700,000	
Holland	600,000	
Mexico	600,000	
Italy	400,000	
Turkey	400,000	
Sweden	300,000	
Servia	200,000	
Peru	200,000	
Bulgaria	100,000	
Roumania	100,000	
	159,600,000	14·5
British Empire, except United Kingdom	36,700,000	3·4
TOTAL FOR ALL THE WORLD	1,095,300,000	100·0

The little kingdom of Belgium, which produces very nearly as much coal as the great Empire of Russia, is perhaps the most striking illustration the world affords of the extraordinary effects produced by the possession of power. Belgium is the smallest kingdom of Europe, but she contains the densest population. Her total area is but a little over 11,000 square miles. She is thus about twice as big as Yorkshire; yet the last census—that of 1900—showed her to have a population of nearly 7,000,000 people, or nearly 590 persons per square mile, against 290 per square mile in Germany, and 375 per square mile in the United Kingdom. The explanation is chiefly to be found in the fact that Belgium has about 1000 square miles of rich coal area. In addition to the basins of Hainault and Liége, which have long been worked profitably, important fresh discoveries have recently been made, the new coalfield of the Campine containing, it is estimated, over 500,000,000 tons of coal. Belgium, as a consequence, is highly industrialised; and the effect upon her external trade is to make her, for her size, a very vigorous exporter of manufactures, which in many cases compete effectively with those of the great industrial countries.

The Smaller Countries of Europe that have Very Little Coal

Unfortunately for Europe and the white races generally, and especially so for the countries concerned, the remainder of Europe possesses very little coal. It will be seen that Spain, Holland, Italy, Turkey, Sweden, Servia, Bulgaria, and Roumania are indeed named in the table on this page, but little more than named. Between them they produce in a year much less than 10,000,000 tons of coal, or far less than the variation in British production in a year. As a consequence, the populations of these lands are chiefly engaged in agriculture.

Spain, which bulks most largely in the remaining European States in the coal list, has been estimated to possess mines containing 3500 million tons of coal. What this means may be realised when it is remembered that the United States is now producing nearly 500,000,000 tons in a single year—a rate which would exhaust the Spanish mines in seven years. The real meaning of this is that Spain is merely a nominal coal producer. It is a fact with very remarkable consequences.

The Spanish Iron Mines that are Worked Chiefly for the Benefit of Foreigners

Spain is exceedingly rich in iron ore, but because of her lack of power the Spanish iron ore mines are worked chiefly for the benefit of foreigners. British and German ironmasters compete for the Spanish iron supplies, and tens of thousands of Britons and Germans earn a livelihood based on the magnificent ores of Bilbao. In some cases the Spanish iron mines are for practical purposes owned by foreigners, so that in truth an iron mine may be only nominally in Bilbao and only nominally Spanish. Again we have forcibly illustrated the effect

upon commerce of the possession of large-scale power. If Spain had the coal mines of the United States, her iron ore would be smelted at home, and the Spanish export trade in iron ore would no longer exist. As things are, Spain ships to the United Kingdom about 3,000,000 tons of iron ore every year.

More remarkable still is the case of Italy. Here is a great nation, with a population of about 35,000,000 people, who, at the beginning of the twentieth century, and in the age of coal, find themselves almost entirely wanting in the most important factor in modern work. The tiny production figure given in the table refers to lignite and not to coal proper, and even of lignite the production amounts to but 400,000 tons a year—an almost negligible quantity. In view of this fact, the industrial progress of modern Italy can only be regarded as remarkable. It is largely based upon the development of water-power. The urgent spur of necessity has prompted Italian engineers to develop the considerable water-power of the peninsula, and upon this vitally important work a not inconsiderable industrial output has been founded. In Northern Italy, the cotton mills are being electrified. Milan is yearly consuming additional electricity based on "white coal."

The Development of "White Coal" in Italy and Switzerland

Great care is being taken not to entrench upon irrigation, this danger being met by a suitable storage system. Among the cities of from 10,000 to 50,000 inhabitants now supplied with electricity are Vercelli, Novara, Pavia, Bergamo, Brescia, Verona, Voghera, Alessandria, Mantua, Vicenza, and Intra. Many of these have become important manufacturing centres through hydro-electrical installations. The city of Como, one of the principal silk centres of Europe, draws power from the lake of Lugano through a line 27 miles long. Verona, which the mind instinctively connects with one of the world's most famous romances, has, in 1912, prosperous factories fed with electricity from water-power. In Venice, too, there are important electrical developments.

Similarly Switzerland has endeavoured to develop "white coal" for want of the black variety. She has a little inferior anthracite, but the total area of all her available coal and lignite measures is little more than 200 acres. A great deal of good work has been done in developing water-power, but, even so, Switzerland is hard put to it to maintain some of her chief industries. The most telling example is the watch industry. For centuries the Swiss watchmaker has justly had a world-wide reputation based on ingenuity and skill. Yet we find a recent official report on the Swiss watch industry stating that the transfer of this branch of trade across the frontier is a question engaging the attention of those concerned; and various suggestions are being considered for arresting such a movement and preserving this important and characteristic industry for the Swiss people.

The Natural Wealth of Countries who Cannot Make Use of It

The case of Sweden, which figures in the table for an annual coal production of 300,000 tons, is similar to the case of Spain. Sweden has been estimated to possess 40,000,000 tons of coal—an amount, that is, which is raised in the United Kingdom every two months. Consequently, Sweden, which, like Spain, is exceedingly rich in iron ore, is not a great iron producing country—although her charcoal iron has a fine reputation for certain special uses—but a great iron ore exporting country. Scandinavia is a rich iron land, and the best Scandinavian deposits, having few equals in the new world or the old, are found in Sweden. Germany, and to a less extent the United Kingdom, import enormous quantities of ore every year, Germany alone taking nearly 2,000,000 tons.

Again we see the natural wealth of one country of more use to the foreigner than to the native, because the foreigner possesses the means of power control denied to the native. In the last year or two Sweden appears to have awakened to the economic disadvantages which she suffers, and there has been much activity in developing her not inconsiderable water-power.

How Sweden is Adding to Her National Store of Power

In 1910 one public and twenty private water-power installations were completed, with a maximum output of over 100,000 horse-power. In 1911 State and private enterprise is again adding a further 100,000 horse-power to the national store; and there is no doubt that the near future will see other very great developments, and consequent changes, in the nature of Swedish commerce. It would be idle to suppose, however, that by any possible efforts of this kind Sweden could hope to rival the leading power owning countries. Germany and the United States have not

INDUSTRIAL DEVELOPMENT IN THE EAST

There is no doubt that Japan will take a high place as an industrial power in the twentieth century, and its rapid rise in industry is hardly less striking than its rise in political and military power. This photograph of a great silk factory in Japan suggests that the Japanese people are likely to be serious competitors of Western nations in the years to come.

only coal but water power. One single power scheme in the United States now being carried out, that at the Des Moines Rapids on the Mississippi, will have an output of electrical energy equal to all that Sweden has developed in two years.

The sister Scandinavian kingdom of Norway has no coal output, but is the fortunate possessor of water-powers which she is wisely developing. For example, the great waterfall at Tinfos is being utilised for the manufacture of nitrogen from the air, the necessary electrical power for the process being very cheaply made.

Denmark, Holland, and Portugal are very poorly furnished with either coal or water power. Turning to the south-east of Europe, there are some fair deposits of fuel, chiefly lignite, in the Balkans, but the quantities are almost negligible in relation to the needs of large scale manufacturing.

In our survey of the British Empire we have already seen that the entire continent of Africa is very poorly furnished in coal. The riches of the North American continent, and the not inconsiderable power supplies of Australasia, have been reviewed. It remains to deal with the difficult and interesting problem of Asia.

The Immense Coalfields of the Chief Nations of the Far East

It is a striking and significant fact that two Asiatic nations, Japan and China, stand next to Belgium in point of coal output. Japan has in a very few years risen to the position of a considerable producer. As recently as 1890 her output was less than 3,000,000 tons a year; in 1907 it was 13,000,000 tons, and for 1911 it will probably be 16,000,000 tons. The Japanese coalfields are supposed to have an area of about one-half of those of the United Kingdom, but they are not nearly as rich in content, and there is no reason to suppose that Japan will ever become a really great producer. We may be quite sure, however, that her resources, for what they are worth, will in the future be worked as energetically as those of the European nations, and we may expect to see Japan take a high place as an industrial power in the twentieth century.

It is when we turn to China that we find a coal nation of the first rank. The small Chinese production shown on page 743 is exceedingly misleading as a test of the richness of the coal resources of China. So great are they that it is difficult to exaggerate either their importance or the prospects of Chinese industry which must follow upon their proper development. The United States has a coal area of about 200,000 square miles. China has a coal area of 232,500 square miles, to realise which we have to imagine *a coalfield twice as great as the entire area of the British Isles.*

The Extraordinary Richness of China in the Source of industrial Power

It is probable, too, that this is but a conservative estimate, since exploration can scarcely have been thorough. The deposits are exceedingly rich in available coal; and it is probable that the bituminous coal and anthracite available in China at depths making it commercially profitable to work them are twice as great as those of the United States. According to Baron F. von Richthofen, China has available 630,000 million tons of bituminous coal and as much anthracite. Let us compare the other three great coal nations.

CHINA'S LEAD IN COAL

Showing the tons estimated to be available.

China	1,200,000,000,000 tons
United States	681,000,000,000 tons
German Empire ..	415,300,000,000 tons
United Kingdom ..	145,600,000,000 tons

While these figures can only be accepted as approximate estimates in each case, there can be little doubt that China possesses at least as much coal as the United States, Germany, and the United Kingdom together.

Coal has a wide distribution in the Chinese Empire, and there are important fields in the north-east, in the west, and in the south. In the north-eastern field the deposits are magnificent. According to accredited estimates, the average thickness of the beds is, for Kaiping, 18 ft.; for Wangping, 35 ft.; for Fangshan, 20 ft.; for Ping-Ting, 20 ft.; and for Tse-Chou, 22 ft. These fields together represent 12,500 square miles of coal, with a content of 350,000 million tons!

The Arrested Development of the Yellow Races

The coalfields of Shansi may be the richest in the world; they have an area of 13,500 square miles, and there are several seams of fine anthracite, the main seam being 18 ft. to 27 ft. in thickness, and continuous over a huge area. It is a fact more easily stated than realised.

What may be termed the arrested development of the Yellow Races is a phenomenon of exceeding interest. It is not merely that the Chinese are a civilised people; they were civilised when the United Kingdom was peopled with painted

savages. China "witnessed the rise to glory and the decay of Egypt, Assyria, Babylonia, Persia, Greece, and Rome, and still remains the only monument of ages long bygone." Tens of centuries ago, China had attained to a civilisation of no mean order. It is difficult to explain why that civilisation was arrested, and why in every department of life progress came to a standstill. Why, for example, having won a certain knowledge of astronomy, did the Chinese intellect not pursue the subject to independent discovery of the brilliant revelations of the Cosmos made in the far newer Western civilisation? Why, again, did China, which knew the value of coal long centuries ago, and had such a bountiful supply, not discover what power could be unlocked for the burning of it?

Seven hundred years ago Marco Polo, the Italian, travelling to far Cathay from what was, and is, a coal-less land, found the Chinese using coal for fuel. He tells us that "Throughout this province there is found a sort of black stone, which they dig out of the mountains, where it runs in veins. When lighted, it burns like charcoal, and retains the fire much better than wood; in so much that it may be preserved during the night, and in the morning be found still burning. These stones do not flame, except a little when first lighted, but during their ignition give out a considerable heat. It is true there is no scarcity of wood in the country, but the multitude of inhabitants is so immense, and their stoves and baths, which they are continually heating, so numerous, that the quantity could not supply the demand; for there is no person who does not frequent the warm bath at least three times in the week, and during the winter daily, if it is in their power. Every man of rank and wealth has one in his house for his own use; and the stock of wood must soon prove inadequate to such consumption; whereas these stones may be had in the greatest abundance and at a cheap rate."

We can imagine that this passage must have been thought a traveller's tale by many of the Venetians who first read their compatriot's marvellous story; to-day we know that the "black stones" are even more marvellous than they must have been considered to be in the Italy of the thirteenth century. The passage, too, is valuable as reminding us how long the Chinese have been a civilised people, bathing themselves religiously in an age when many European potentates neither drank water nor washed in it if they could help it. Whatever the explanation, the Chinese development was stayed, and not until recent years has mining in the modern sense been applied to this mighty Eastern source of power. Who shall put a limit to the industrial developments of China when once the Celestial Empire gets under way with modern appliances? Mining and manufacturing are easily transplanted to a new land—"all men can grow the flowers now, for all have got the seed." The foreign capitalist is eager to exploit Chinese coal for his own advantage, but we must remember Chinese coal cannot be developed for the foreigner's benefit alone; it is impossible for China herself not to gain, since the economic power of coal can only be fully developed in the place where the fuel is got. That China is intellectually astir it is impossible longer to doubt. The great revolution of 1911, whatever its outcome, is the sign and portent of a stirring of life and of thought which cannot be controlled, and which will find expression in many forms.

THE RAILWAY THAT OPENS UP CENTRAL ASIA
Copper, iron, and coal abound in Central Asia, but the absence of roads of any kind long made even rich deposits too expensive to work. The construction of the six-thousand-mile Trans-Siberian Railway, at a cost of many millions of pounds, has, however, opened up immense possibilities of commercial development in the region through which it runs.

Few realise how rapidly industrial developments are proceeding in the East. In 1911 there are many Chinese mines that are being worked on modern principles. The Kaiping collieries in Chihli have been owned since 1900 by a British

company, and have a daily capacity of 6000 tons. In the same province the Lanchow collieries are owned and worked, in opposition to the Kaiping undertaking, by a Chinese company which employs German engineers; the daily capacity is 5000 tons. There is also the Ching-Ching colliery in Chihli, partly owned by the Chinese Government, with a daily capacity of 1000 tons, and the Mengtchou mines owned by an Anglo-Chinese syndicate. In Honan province the Pekin Syndicate, Limited, a British concern, has important mines at Ching-Hua-Chen, which were opened in 1905. In Eastern Shansi, a very rich coal district, a Chinese mining company has collieries at Ping-ting-chou.

The Mighty Centres of Industrial Effort that May Arise in the Far East

Another Chinese undertaking with German engineers works collieries at Tingh-siang in Kiangsi province, which have an output of 600,000 tons a year. A German company opened collieries in 1902 at Fangtze, and a Chino-German company is mining in Southern Shantung. These and other enterprises, native, partly native, and foreign, are, it is true, but touching the fringe of China's mineral wealth, but the output is rapidly increasing; and it is impossible to doubt that *the course of another fifteen years will see China the fourth coal producer in the world.* Thereafter she will gain rapidly upon Britain and Germany.

Then will be set up in the Far East mighty centres of modern industrial effort, which will entirely change the position of China in the world of trade and in the category of nations. For China is as rich in other minerals as in coal. Merely to speak of what is known, she has enormous iron deposits, and it may be surmised that much remains to be proved. On the Yangtze, seventy miles below Hankow, there exists one of the richest iron mines in the world.

When the Hundreds of Millions of Chinese People Find China's Power

The ore exposed on the surface is estimated at 500,000,000 tons. It may well be that China is the richest iron country as well as the richest coal country. There are also proved and valuable deposits of copper, lead, tin, mercury, antimony, and zinc, and of gold, silver, platinum, and nickel. Other important minerals found in abundance include petroleum, marble, porphyry, china clay, sandstone, salt, sulphur, plumbago, alum, asbestos, and precious stones in variety. We have to imagine what may, what will, be done with all these good gifts when the latent industrial capacity of hundreds of millions of strong and intelligent people are reinforced by the utilisation of the potency of a coal area of considerably over 200,000 square miles.

It would be a profound error to suppose that such a change in China as would be necessarily born of modern power development would be of injury to the commercial interests of the Western nations. In the days when China, as we need not hesitate to prophesy, will be a great and flourishing industrial nation, she will make exchanges with Europe and America far exceeding in value her existing commerce. Chinese import trade is now worth but about £50,000,000 a year.

The course of the twentieth century may see this figure multiplied fivefold or more as China builds, upon the sure foundation of power which we have described, a vast and many-sided industry and commerce. It was doubtless the policy of exclusion, and the consequent lack of contact with the intellects of other races, which contributed to that peculiar arrest of growth which marked the history of China. A wider commerce with the world, and the consequent enlargement of the Chinese mental horizon, may give such an impulse to the Chinese people as to reveal unsuspected qualities in what is recognised as excellent material by those who know China best.

The Change that May Come Over the Face of Asia

Let us proceed with our survey of the world's wealth in coal. A great deal of coal occurs in Siberia, in Turkey, in Asia, and in Western Asia, but it does not appear that these places have the abundance of fuel of Eastern Asia. There must necessarily be some uncertainty on the point, because of lack of development in Siberia, or Asia Minor, or Persia. The Trans-Siberian railway will doubtless lead to great mineral developments, and, indeed, it certainly runs through some very fine coal reserves. In Asia Minor the Turk has done little with the excellent coal resources which exist in many of its provinces. The day may come, however, when the valleys of the Euphrates and the Tigris will once again be fertile through modern irrigation, and when, with latent power resources developed, the great area of Turkey in Asia will support tens of millions of prosperous agricultural and industrial workers.

It is not a little strange that the nations of Latin-America, which now number between them, as is little realised in Europe,

some 70,000,000 people, should be almost entirely lacking in coal. Even in North America the great coal deposits have relatively little extent in Mexico. We say relatively, because Mexico is by no means lacking in fuel. South America has coal in Colombia, Argentina, Brazil, Peru, and Chili, but the deposits do not appear to be of great importance. The remarkable recent growth of wealth and population in the South American nations has been due, not to industrial developments in these parts of the world, but to what we have termed the second great determinant of the distribution of population—fertility.

It remains to be seen whether, by the development of water-power or other means, South America will be able to add flourishing industries to a great agriculture. In minerals other than coal South America is rich, and South American " white coal " is a factor to be reckoned with. The great rivers of South America, with their numerous waterfalls, should be able to sustain industry on a big scale. We may note that already São Paulo, in Brazil, is lit with electricity derived from water-power, and it is expected that this town will soon be a manufacturing centre happily free from the great social nuisance of dirt which the use of coal brings.

We have now surveyed broadly all the world of power as it has as yet been revealed to us. The three corners of the world are rapidly being brought together; and while there is something of uncertainty in the factors of power ownership, and no less in regard to the possibilities of the scientific use of power supplies, it is probable that we have limned with essential accuracy the outlines of the position as it is. The causes of the main existing currents of trade, and of the nature and extent of the commerce of the various nations, can only be understood by reference to the main factors we have been considering; and the probabilities of future development may be prophesied in the light of them.

It was the knowledge and understanding of such factors, although in more limited degree than is ours to-day, which enabled far-seeing men to predict fifty years ago the future industrial and commercial eminence of the United States. With greater means of information, we are now able to conceive a great industrial future, in varying degree, for Canada and China, for Japan and South America, for Australia and New Zealand, and, happily, not for these alone. Our knowledge of the underlying reasons for commerce enables us to rejoice in the prospect of these developments, in the certainty that no one part of the world becomes rich because another is poor, and that no nation becomes the poorer because wealth is built up in another land. The greater the production of wealth in each of the many lands we have examined, the brighter the prospect of healthy gain for each citizen of the commercial world.

THE AMAZON RIVER IN SOUTH AMERICA, WHICH MAY BECOME A SOURCE OF VAST INDUSTRIAL POWER

It is difficult to resist the conclusion that the Amazon River may become the seat of great industrial power in the future. South America has developed marvellously in agriculture, owing to the fertility of the soil; and by harnessing the great water-power of the rapids of the Amazon, South America will doubtless enrich this part of the world with flourishing industries.

WOMAN THE DISCOVERER OF AGRICULTURE

Primitive woman, we may safely assume, collected wild grass-seeds, nuts, and acorns; and while her husband was busy hunting, she invented the arts of agriculture, which domesticated man, attached him closely to the soil, and made civilisation possible.

THE TRIUMPH OF WOMAN

How the Women of Primitive Days Built the First Homes, Domesticated Man, and Gave Birth to Agriculture, Industry, and the Arts

WOMAN AS THE MOTHER OF CIVILISATION

"WOMEN," said Lord Chesterfield, "are children of a larger growth." What the cynic said in jest, the man of science asserts in earnest. Woman is more of a child than man is. This is a fact not merely of human life, for the difference between the sexes is similar in animal life generally.

On the whole, the adult male diverges to a greater extent from the infantine type than the adult female. From this it has sometimes been concluded that woman is only "undeveloped man." This is a misleading statement, if understood to mean that woman is inferior to man as he is at present. It would be truer to say that woman is higher in the line of evolution than man. Like the child, but in a less degree, she is the undeveloped man of the future. Practically all adult males represent only a blind alley lying off the open lines of development. They are finished and finite products, while the child—and the woman in so far as she resembles the child—are indicative of further growth.

Man, in short, is the instrument of the present; the child is the promise of the future. Woman stands midway between them, partly an instrument of the present, and partly indicative of human evolution. Already the large-headed, delicate-faced, small-boned man of urban civilisation has developed away from the savage adult, and approached to the physical structure of the woman.

A few years ago it was commonly thought that the brain of man was much larger than the brain of woman. It has now been found, however, that, in proportion to the size of her body, woman has a larger brain. Woman's brain-weight is to man's as 90 is to 100; but then woman's body-weight is to man's as only 83 is to 100. Professor L. Manouvrier, the French anthropologist, goes further than this, and estimates that the active organic mass of woman's body is to that of man's as, at most, 70 is to 100. Thus it looks as though woman has, in proportion to her body-weight, a little more brain-weight than man. She is also more hairless and more delicately built. In short, she is a child of a larger growth, and she can congratulate herself on this fact. Her superiority in comparative brain-mass, however, implies no intellectual superiority, but is merely a characteristic of short people and children. On the other hand, there seems to be no reason for the belief that women are naturally slightly less intelligent than men. Many of the differences between the adult sexes of civilised communities are due to differences in education. By education we do not mean only mental training, but mainly muscular education, bearing on the individual development of the nervous organisation.

Man undoubtedly possesses some natural advantages over woman—he is stronger in body, for instance, while the woman is stronger in constitution. This fact has determined the natural division of labour between the sexes. From the beginning man has been the fighting animal, and woman the domesticating force. Woman has made the home, and man has guarded it. Man has invented the weapons of human supremacy over the wild beast, woman has discovered the means of turning plants into food. Man has generally undertaken the work requiring great effort exerted suddenly and for a short space of time, woman has done most of the hard drudgery of existence.

In appearance, a woman of a savage type is the most oppressed creature on the earth. She can still be seen, among the lower hunters, trudging along, carrying a hundred pounds of household utensils, with often her last-born child slung behind her back or straddling over her shoulders. She will walk like this for twenty miles a day. In

front of her strides her husband, with nothing in his hands except some weapon of defence. "It does look bad," says Bishop Selwyn, "but it is really an excellent division of labour. A savage woman can carry a very heavy burden, but she cannot defend herself as well as a man can."

With a little alteration, this picture of modern savage life can be made to represent the primitive state of the relation of the sexes. The woman bore all the burden, and man walked in front of her with his club or his stone axe, ready to defend his mate and his young from beast of prey or human rival. When human warfare began, more routine work fell on the woman, and more risk and danger on the man. Probably for hundreds of thousands of years the inventive genius of the human male was spent chiefly in devising instruments of destruction. He threw away his wooden club, and began to shape rude axes and weapons of bone and flint; he became cunning in making traps, and wise in the ways of both the animals he feared and the animals he hunted for food.

Man the Hunter and Woman the Founder of the Home

First in hunting, and then in war, he learnt to act in concert with bands of his fellow-men, and laid the foundation for those social co-operations on a large scale out of which grew the clan, the tribe, and the nation. His field of action thus became larger than the woman's, and in favourable circumstances he seems to have developed somewhat larger powers of mind. These powers, however, he did not apply directly to the development of home life.

It was left to woman, in all probability, to originate the industries of peace. Perhaps man found the cave, but it was woman who built the house. Moreover, there are grounds for believing that the primitive house came into use before the cave. The lowest of the lower hunters has no fixed place of abode. He cannot stay long in one place, as he soon exhausts the game and other natural resources. Even a hunter of the higher type, like the American Indian, wanted about 2000 square miles for himself; at least, he possessed this in New York State before the white settler drove him away. As a rule, a thousand farmers can live on the area a single hunter requires.

At the present day, Australian natives sometimes travel twenty miles between sunrise and sunset. The woman carries all the furniture. Here is a list of it, made by Sir George Grey: A flat stone to pound roots with, earth to mix with the roots, quartz to make knives and spears of, stones for fashioning into axes, cakes of gum used in mending weapons and sticking down the bindings that kept stone instruments enclosed in their wooden handles, kangaroo sinews for thread, needles made of the small bones of the kangaroo, opossum hair for waistbelts, shavings of kangaroo skin to polish spears, some grease, and stone knives and axes. In addition to all these things, the savage woman carries a digging-stick, with which she digs up roots. It is also her building implement.

The Wandering Woman who Carries Her House About the World

When the family arrives at a good place to camp, the woman digs eight holes with her digging-stick. Into these holes she puts eight poles. The upper ends of the poles slant towards each other and meet in such a way that they do not require to be tied together, thanks to the art with which the woman builds her house. Through the poles the woman laces smaller sticks, and over them she places a layer of grass and leaves or pieces of bark. Thus is formed a small rainproof shelter, serving fairly well as a temporary dwelling-place, but representing scarcely any advance on a bird's nest. The women of the Bushman race, which is somewhat higher in culture than the lowest of Australian natives, make a portable shelter of mats. The Red Indian woman also carries her wigwam with her when she goes on a march. It is a valuable thing, made out of the hides of animals.

Everything thus goes to show that the female of the earliest wandering races was the original home-builder. Shelter was more important to her than it was to the man, for she had a frail child to protect from the inclemencies of the weather.

The Invention of Clothes in a Europe that Grew Colder and Colder

Perhaps it was also for the sake of the child that woman invented clothes. Among the rude stone axes of our earliest predecessors in Europe are found the skin-scrapers used by their women. Until the Rev. Frederick Smith recently pointed out that these skin-scrapers are to be found in considerable number among the most ancient of prehistoric remains, no evidence of the activities of very early women had been discovered. But now it seems clear that our remotest ancestors were clothed by their wives and daughters. It was growing cold in Europe in those far distant days, and it is probable that the women began by making dresses for themselves.

This stage of culture was recently found among the natives of Tasmania. The men went naked, but the women wore a loose covering of skins. Man, the hunter, was certainly the last to take to clothing, for it impeded him in his craft, until he became well used to it. With few exceptions, savage races throughout the world still throw on women the task of working up the hides of beasts into clothes, tent coverings, and canoe coverings.

The First Tailor and the First Weaver of the Early World

There is some doubt whether woman invented sewing; at least, Professor W. I. Thomas, of Chicago, is inclined to give man the credit for discovering the uses of the bone needle and the tough tendons from the back or leg of deer and other mammals. It is supposed that these threads of sinew were first used by the hunter in setting snares, and then adapted by him for the purpose of sewing skins together. However this may be, the savage woman now is usually the tailor as well as the skin-dresser of her tribe; she is also the shoemaker and the tentmaker. It is true that the males of the North American Indians make their war-dresses themselves.

Again, the young Zulu has, by custom, to make for his bride a petticoat reaching from her bosom to her knees; he scrapes and rubs the hide until it is as soft and as smooth as a fine cloth. But this, too, seems to be a rite. On the whole, all the evidence available goes to show that woman invented clothing.

Woman was also the first weaver. She began with reeds and green, flexible twigs. Being the bearer of burdens and the fetcher of water, she wanted something in which to carry her belongings. She had already practised a rude kind of basketry in weaving twigs into hurdles as a shelter against rain.

The Far-off Beginning of the Art of the Potter

The very lowest of known savages can at least weave twigs together in a rough fashion. Above them are the tribes which make rough hampers—the women, of course, doing the work. Then baskets of all materials appear—wood, bark, bast, grass, skins, and roots. The best example of this kind of woman's work is a basket of roots or grass, woven with a two-ply twine, in which the twines are driven so close together as to make the vessel water-tight. Here we come to the origin of pottery.

These woven vessels are often as water-tight as goatskins or stoneware, and they are used for cooking. Water and food are placed in them, and stones are heated in a fire close by and dropped into the water. When the baskets showed signs of wear they were plastered with wet clay, and when this dried hard the vessel was able to be placed on the fire. The remains of the most primitive pottery are distinguished by marks of twine-woven basketry, showing that the pot was made by plastering a basket with clay and then burning it. This, however, is a laborious and roundabout process; and the next advance that woman made was to weave a pot. She rolled a piece of clay into a long ribbon, and, taking a low basket bowl, built up inside it a series of clay rings. On reaching the level of the bowl, she still kept twining the ribbon of clay round and round until she had formed a vessel three or four times higher than the bowl. Each coil of clay was firmly pressed against the coil beneath, so that the vessel became water-proof. It was then set to dry, and rubbed down with a smooth stone.

The Surprising Things that Came Out of the Primitive Woman's Basket

The next step that woman took can be traced among the women of New Caledonia. Instead of twining a ribbon of clay inside a basket bowl, they place the wet clay in an old clay bowl, which they keep turning rapidly as they mould the clay with their fingers. Here we find the most primitive form of the potter's wheel: so we must acknowledge that woman is the entire inventor of one of the most useful of domestic arts.

That primitive basket of hers was, indeed, like the basket of the modern conjurer. Out of it came a number of surprising things. Opposed to Professor Thomas are several men of science of high authority who hold that women invented the needle. In making her little house of boughs and twigs she used a stick to interlace the branches together. In the finer work of basketry the stick was refined into a little sharp wooden awl. Then came the finer bone awl, which, Professor Mason, of the United States National Museum, says, is found in almost all the graves of primitive woman. Surely it was she who first thought of boring a hole in the tool that she alone used, and used constantly.

So we must conclude, against Professor Thomas, that out of the basket of the woman came the needle. Then followed rope and cloth.

Primitive cloth was made out of the fibre of the bark and leaf of various trees. For instance, filaments as fine as silk can

be obtained by heckling the fibrous bark of the American cedar with a bone knife. This was the method adopted by the Redskin women around Fraser River in British Columbia; while in the warmer lands of South America, and in Africa and Polynesia, cocoa bark, palm-leaf fibre, and pita fibre were used. The thread was first spun by fastening the strands to a stone, which was twirled round till the yarn was sufficiently twisted. The yarn was then wound upon the stone, and the process was repeated over and over. Thus the idea of a spindle was discovered, and the spindle itself, with its spindle whorl, followed.

The Spinning-loom that Came Out of the Magic Basket

And then, out of the magic basket, woman, the inventor of all the domestic arts, brought forth the spinning-loom. It first consisted of two rows of sticks, fixed opposite to each other in the ground. The warp was fastened to these sticks, and the threads of the woof were passed through with the hand, and pressed back by a rude wooden comb. The simplest form of hand-loom is to be seen in use among the savage women of British Guiana. They use it, for making their aprons. The frame consists of two rods, one flexible and bent in a semi-circle, the other straight and having its ends tied to the ends of the bent rod. Thus it formed a simple frame, shaped like the letter D. The warp threads pass from one rod to the other, and the woof is woven into them by means of a slender stick on which the yarn is wound. Long before the white man came to America, hemp and cotton were used by tribes in the lowest stage of culture. Even the cannibal Carib woman of the West Indies had a primitive cotton plantation.

Agriculture, the Most Important of All the Achievements of Women

This brings us to the most important of all the achievements of woman. There is little or no doubt that she discovered agriculture, and thus domesticated man and founded civilisation. Neither the lower nor the higher hunters are able to keep themselves and their families on the spoils of the chase. Primitive woman is the chief food-bringer. In her exploitation of her peculiar kingdom—the vegetable world—woman first appears in the act of taking from the hands of Nature those fruits and other parts of the plant which are ready to be eaten. On her next journey she ventures a step further. With digging-stick and carrying basket she goes out in search of roots which have to be roasted or boiled with hot stones to make them human food. Then, on her third journey—she is still taking it in the wilder parts of Australia—she gathers the seed of grasses. In our list of the furniture of the Australian woman we omitted a curious stone about eighteen inches square and several inches thick. It seems a far stretch from one of our huge, steam-driven steel mills to this square of stone which the blackfellow's wife carries with her in all her long wanderings, but all the steps in the development from this stone to the modern mill can easily be traced.

Having collected the seeding grass, the woman digs a hole twelve inches deep, and puts the bundle in it and stamps on the grass until the seed has fallen out and worked to the bottom. She then clears the hole and collects the seed, and winnows it in a large bowl, using her breath if no wind is blowing. After this the seed is laboriously ground on the square stone, and moistened and scraped back into the bowl, and eaten either cooked or raw.

The Prehistoric Women of Europe who Ground the Corn

This is the nearest that the natives of Australia have approached to the arts of agriculture. The almost extinct Bushmen were scarcely more advanced. Their women collected the seeds of wild grasses, which they pounded in mortars hollowed out of the rock. The Bushmen lived in a land where game was very abundant; and it seems likely that their women failed, for want of the pressure of hunger, to take the grand step in cultivating the plants that grew around them. Stones with a curious resemblance to mullers have been found among the oldest prehistoric remains in Great Britain. A muller is a flat stone which the grinder takes in her hand when she is pounding seeds or nuts or acorns on a flat stone, in the hollow of a rock, or in a portable mortar.

So it looks as though the prehistoric woman of Europe was on the same level as her modern sister in California—who, a few years ago, harvested the acorn, the pine nut, and the seeds of sand grass. With the same free movement of the body with which a modern washerwoman washes clothes, her savage sister rubs her muller up and down and sideways upon the nether slab. The work is done in a kneeling position, and it is very hard. Hollowing out the nether stone and converting it into a mortar make the task more easy;

WOMAN—THE INVENTOR OF POTTERY

It was woman, no doubt, who first wove a shelter of interlacing twigs to shield her child from storm and cold; then, improving in the art of plaiting, she made a basket; and by lining this with clay and burning it over a fire she discovered pottery.

and from the mortar is developed the hand-mill, worked by two women.

In northern California, where, as in ancient Britain, acorns are ground for food, we find the most primitive form of existing granary. It consists of a wicker hamper, holding about a bushel, and it is set up, full of acorns, in the huts. In southern California the wicker granaries are very large. Roughly thatched, and lifted by wooden pillars above the ground, they show quite as much art and foresight as the ricks our farmers build.

The Work of Women Among Savage Races in these Days

There is ample proof that among the three typical divisions of mankind still in savagery—the American Indian, the negroid races, and the Malayo-Polynesians—the women are the builders and owners of the first caches, granaries, and storehouses. There is every reason to believe that the same state of things obtained among the now higher peoples when they were at a low stage of culture.

And if we admit that woman throughout the world was the founder and owner of the primitive granary, we must allow that she was the inventor of agriculture. For the granary is the last step to the tilled and sown field. In America woman took a grass, which is still to be found growing wild, and cultivated it into Indian corn. In Africa she grew millet and mealies, as she does now. In Asia she transformed the wild rice; and probably in the fields of Asia and Europe she cultivated wheat. The general fact that woman still remains, among practically all existing savage races, the cultivator and the harvester is additional evidence that she may have been the original founder of the arts of agriculture.

Women domesticated man, the cat, and the plant; man tamed the dog, reindeer, cattle, sheep, and various beasts of burden. Both of these achievements made for a settled home and an abundant food supply.

The Woman's Step that is Probably the Most Important Advance Made by Humanity

In some parts of the world, where—until the advent of the white man—cattle-keeping on a large scale was unknown, it was given entirely to woman to strike down the path leading to civilisation. In several regions of the Old World, however, man seems to have taken to keeping and breeding cattle before woman engaged in farming in a large way. Nevertheless, the primitive stock-breeder remains a semi-nomad, wandering from summer pasturages to winter pasturages. As we see in ancient Ireland, cattle raids and tribal quarrels kept him continually at war with his neighbours. As a rule, it is not until a people settles down to agriculture or industry that it falls into a way of life sufficiently settled for a civilisation to grow out of it. To woman, therefore, must be attributed the most important advance made by humanity.

We must remember that her life was fairly easy in the pastoral days, when she made her last and greatest discovery. Man not only guarded and largely fed her and her children, but he took over a great deal of the routine work. He drove the herds afield and shielded them from beasts of prey and human foes. Often he was compelled to fight as hard as he did in the hunting age, and he had still to conquer the wild beasts that ravaged his herds and flocks. He was more continually busy than when he lived on the game he trapped and slew, but his new way of life relieved the woman of some of her heaviest burdens. These burdens, it must clearly be understood, were not imposed upon her by man. They fell on her in the natural course of things.

The Division of Labour which has Established Economic Equality Between the Sexes

We must not abuse the poor savage man, it has justly been said, who lies idle in the sun for days after his return from hunting, while his heavily laden wife toils and moils without complaint. For when we bear in view the extreme bursts of exertion required of him in his struggle for food and life with Nature and his fellows, we see that he must use every opportunity of repose to recruit and eke out his brief and hazardous existence. On his strength directly depends the welfare of his wife and offspring.

From the time when man leaped down from the tree to the time when he invented the steam-engine, there has been, all things considered, a fairly equal division of labour between the sexes. Man has done most of the work requiring power used swiftly and violently; he probably discovered the use of fire, leaving woman, of course, to guard it and employ it for cooking. He built the boat which enabled the human race, probably in the Old Stone Age, to spread over the whole habitable world; and he solved the problem of a constant meat and milk supply by domesticating many of the animals he once hunted. He founded religion and philosophy and law, and many of the larger arts of life. Woman, as we have seen, discovered the domestic and agricultural arts; and in all probability she found out the value of herbs.

By working side by side, yet in different directions, man and woman arrived at a condition of economic equality. Woman became an agriculturist, and man a cattle-breeder. This state of things is finely described in the Book of Proverbs.

This was a happy stage in the history of mankind, and on it the ancient poets built their beautiful fable of the Golden Age of the past. We have already traced in previous chapters on the Family and Marriage the effect on woman herself of her increased value from the economic point of view. Her position as daughter, wife, and mother became more stable; desertion and divorce grew rare; the children received more attention, and the general span of human life was lengthened.

This was also the time when women generally began to count politically. Unfortunately, the records of most of the civilised nations do not go back very far. We know very little about the Egyptians of the first dynasty, and much less about the Cretans, who seem to share with them the honour of being the earliest of all the races of mankind to arrive at civilisation.

The Time when Women Began to Count Politically

This happened probably six thousand years ago. Two thousand years later, we find in the laws of the Babylonian king Khammurabi the first clear evidence of the position won by woman in the early agricultural states. Her freedom and dignity were very remarkable. Her husband brought her a dowry, and when he died she became the head of the family. In case of divorce, the innocent wife was given the dower and the custody of the children, and her husband had to pay her an annuity.

Slandering a married woman was as grave a crime as slandering a sacred vestal, and the slanderer was branded, and made, it would seem, a slave for life. In Egypt, moreover, inheritance obtained through the female line, and succession through the mother. As in England in the Elizabethan and Victorian ages, the queens reigned in their own right—like Nitocris of the eighth dynasty, Scemiophrus of the twelfth dynasty, and the renowned Queen Hatshepsut.

The equality of woman with man seems to have extended at times even to the priesthood, for we find women as priestesses in temples dedicated to female divinities. Significant also is the rank occupied by goddesses in the pantheon of the two great agricultural nations of ancient times. In Babylonia, Istar was the mother of all the gods; and down to the days when the Christian Church was founded, the Egyptian Isis, wife of Osiris, was practically supreme among the Egyptian deities. In Assyria, Astarte was the highest goddess; in ancient Arabia the goddess had more power than the god, and so she seems also to have had in Moab and other lands.

The Wife of a Peasant to whom Israel Turned for Advice

Still more significant, in the circumstances, are the power, authority, and place which Deborah won among the monotheistic and republican Jews in the age of the Judges. Scarcely more than a hundred years after the death of Joshua, a woman won the rule over the fierce, warlike tribes from the desert, who still had more of the raiding habits of the Bedouin than the love of peace and settled life of the farmer. Their religion was warlike and wholly masculine; there seemed to be little place in it for women; yet in the time of great national peril it was to the wife of an obscure husbandman that Israel turned for guidance and inspiration.

Energy, will, mother-wit, endurance, and sagacity seem still to be found more in women of the peasant class than in women in other walks of life. In managing ability, indeed, the peasant woman is often superior to her husband.

On the other hand, it is equally patent that woman soon lost much of her monopoly in agriculture. When she had tied man down to the soil and domesticated him, he brought to bear on their common task of tilling the land the powers of mind and body developed in the hardest and most strenuous school of life. Trained to concerted action in hunting and in war, he had greater and better organising force than woman—who still remains very individualistic in thought and feeling in matters not directly related to the home circle.

Man Carries Out the Work in the Field that Woman Discovered

Man transferred to labour the organising capacity he had developed in more violent ways of life; and when he came to settle down as an agriculturist he acted with his fellows on a large scale—clearing the jungle, preparing the land, diverting water-courses, and building roads for the transportation of the products of farming.

Man also brought with him to his new industrial occupations a superior skill in

WOMAN, NO LONGER THE BURDEN-BEARER, BUILDS UP THE COMFORT OF THE HOME

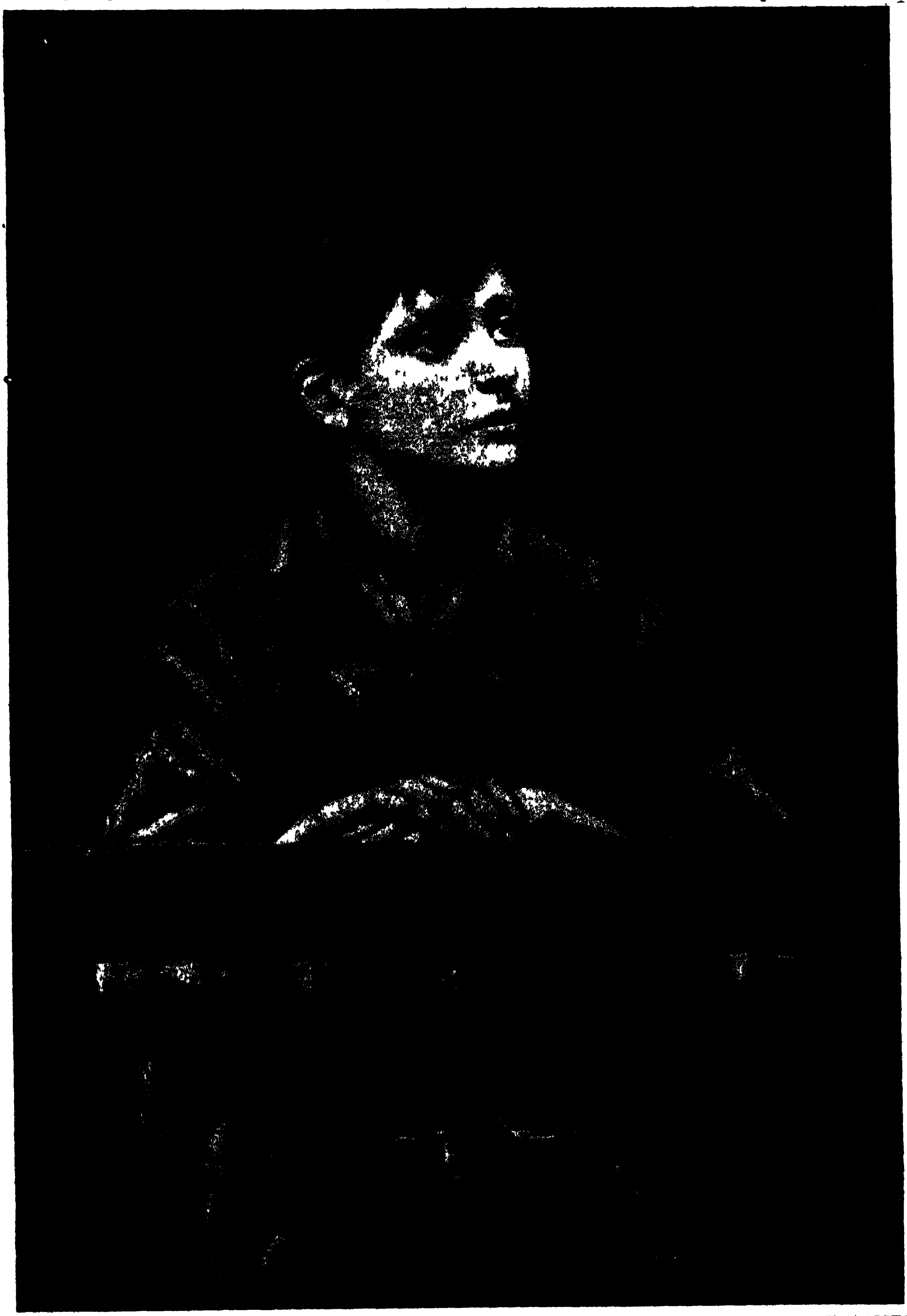
There can be little doubt that woman founded the home ; there can be no doubt at all that in the early days woman was the burden-bearer of mankind. Over the greater part of the world the physical subjection of the mothers of the race has passed away, and woman has became the home-maker, the builder up and maintainer of the comforts of family life. This picture, called "The Laundress," painted by Alice Havers, hangs in the Walker Art Gallery, Liverpool.

HEART ON HER LIPS AND SOUL WITHIN HER EYES—BY J. W. GODWARD

fashioning instruments. For a million years, perhaps, his life had been a life of strains—a continual fight against death in all forms, in all attitudes—and this had stimulated his powers of invention. So when he took at last to making and handling tools, he was greatly helped by his practice in making and handling weapons. Woman first thought of thrusting a stick in the earth and dropping the seed in, and awaiting a meagre harvest, but when man gave his attention to the matter he gradually worked out a remarkable combination of all the materials and powers within his reach. The great rivers by which he settled he split up into little, irrigating, fertilising rivulets of water. The bucket that woman had invented for carrying purposes he placed on a wooden structure beside the stream, and turned it into a sort of pump for watering his far-off fields. The woman's hoe he transformed into a plough, and to this plough he harnessed the animals he had tamed in his semi-nomadic days.

So he went on improving in every direction on the primitive inventions of women; and in the end woman retired from the field that she had discovered, and devoted herself mainly to developing industries of a purely domestic sort. This new division of labour had in some cases a bad effect on the position of woman. In China, in India, and in ancient Greece she was sometimes driven completely indoors, and the door was shut upon her. Woman, the founder and discoverer of the arts that make for happiness, was put under subjection. This was undoubtedly an act of tyranny, and the children at last suffered for the indignities done to the mothers of the race.

A STUDY IN ENVIRONMENT—BY LADY STANLEY



"HIS FIR[illegible] OFFENCE"—THE FAMOUS PICTURE BY LADY DOROTHY STANLEY, WHICH RAISES THE QUESTION OF THE INFLUENCE OF ENVIRONMENT

ARE WE BORN OR MADE?

The Momentous Union of Nature and Nurture in the Making of Human Beings

THE UTMOST THAT EDUCATION CAN DO

"CHARACTER and circumstances," "heredity and environment," "nature and nurture," are pairs of terms which express the two great classes of the factors which make a living thing. The first pair may now be rejected as too loose, for character is partly moulded by circumstances; it is partly a product, and our terminology must avoid any product, but fully describe the factors which, when multiplied together, yield the product—a backbone, a temper, a toe nail, or what not. "Heredity and environment" are correct and useful terms, which, like the rest of the world to-day, we must constantly employ, but as often as not we shall speak of "nature and nurture" instead, following the literary and scientific precedent of Shakespeare and Galton.

Our first business is to define these two categories, upon which the two halves of eugenics are respectively built. If we are to speak of Natural Eugenics and Nurtural Eugenics, we must know exactly what is nature and what is nurture, what is heredity and what is environment. Then we can proceed to estimate these two great factors, and deal with them logically. The facts of biology here guide us to a hair's breadth.

Every human being is composed by the conjugation, fusion, or conception of two cells, one derived from the father and the other from the mother. What those cells bring is the "nature" or "heredity" of the new individual. When they unite they form a single cell, only just visible to the naked eye, though never yet seen but by the All-Seeing. This is the new individual. All the influences which play upon, feed, mould, stimulate, poison, aërate, or otherwise affect the new individual, from the moment of conception to the moment of death, constitute its "nurture" or "environment." How much this term means in the case of a human being, which not only breathes, as all living things do, but also reads, as no other living thing does, we shall see in due course; but we shall see to no profit unless, once and for all, we realise that nurture or environment begins when the individual begins, and ends when the individual ends.

The abrupt and dramatic change of environment called birth is important enough on many grounds, but it is only a change of environment nevertheless, only the transition from the stage of ante-natal nurture to that of post-natal nurture—nurture before birth to nurture after birth. The writer advocates the use of these simple and convenient terms in order to obviate, if possible, the almost universal confusion between ante-natal nurture and heredity. Heredity or inheritance is what is contained in the hereditary material, the two cells which united to form the new being. The nurture of that being—whether through its mother's blood before birth, or its mother's milk after birth, or its breakfast any morning thereafter—is all nurture; and the confusion of thought, shared by too many who should know better, is really inexcusable.

It would not be so if we had no idea of the earliest stages of the new life, and its formation, but we now are possessed, through biology, of all the necessary facts; and they show us clearly that the distinction between heredity and environment, or between nature and nurture, is real, exact, sharp, and unalterable. It need hardly be said that, in this first attempt to present a complete exposition of the new science, we shall rigorously recognise the distinction which biology demonstrates, and that when we speak, at any time, of heredity or "nature" we shall certainly not mean such facts of nurture as, say, the passage of alcohol,

arsenic, lead, the poison of rheumatic fever, or any other substance, into the new life during —or after—ante-natal nurture. Nevertheless, if experience is to be taken as a guide, it will be another twenty years before all who discuss such subjects realise that what happens to a baby before its birth is not heredity. At least let readers of POPULAR SCIENCE avoid this commonest of popular and professional errors.

How Nature and Nurture Act and React on One Another in Developing Human Life

Thus much being clear, the next proposition which biology lays down for our guidance is that every characteristic of every living thing is the *product*—not the *sum*—of both nature and nurture. However good the hereditary material, bad nurture will ruin it; worse—may kill it then and there. However good the nurture, it will fail to turn an ape into a man, a fool into a seer, or a brute into a poet. It follows that we must demand the utmost possible, alike from nature and from nurture, for our eugenic project; and that if we constitute ourselves advocates of either as against the other we are enemies of our cause.

The sequence of argument is clear. Everyone who cares for real things at all wants to make better men and women; and the obvious method is to take more care of them—in all respects, from food for the body to food for the mind. That we have agreed to call nurture. But when the experiment is tried, no doubt imperfectly, but yet with some approach to completeness, the results are unsatisfactory. We institute national education, and many children benefit, but many do not; and those who do not, demonstrate that nurture is not everything, as we shall see in due detail soon. At this point in the argument there arrives the modern student of genetics, the science of heredity, who declares that while we have recognised nurture we have forgotten nature; and this is the new and distinctive contribution of modern eugenics to the problem of making men and women.

It is Worth While to Nurture Well Those who are Not Well Born

As to the importance of, say, diet or housing in promoting the welfare of the race, we are all agreed; but it is the Eugenist alone, in his tiny minority, who says that we must begin at the beginning, which is not diet nor housing—no, not even ante-natal diet and housing—but heredity, or the inherent nature of that which we are trying to feed and house. Perhaps we are trying to make a silk purse out of a sow's ear, and it can't be done. The Eugenist is perfectly right; and all the other party, including the politicians who depend upon the popular vote, must learn from him. The difference between a politician and a thinker is that a politician lives by majorities and a thinker lives by minorities, for his teachers and supporters are very few, but their increase is sure. We in England now are just witnessing the beginnings of that increase, for people are now coming over, in ones and twos, to see that the minority are right who, in all ages, but never so surely as to-day, have declared that the first necessity is to be well born, and the second to be well nurtured.

So far, so good, but we must beware lest the next proposition be that the nurture of those who are, or are supposed to be, not well born is not worth while. That is the pernicious, immoral, brutish, and stupid conclusion to which many recruits, entering the eugenic army in recent years, have committed themselves. If it were to prevail with Eugenists in general the ruin of our good cause would be upon us. But no right cause can fail; and the only danger is lest the acceptance of eugenics by the present generation rather than the next be prejudiced through the disastrous advocacy of those who see in the new truth an instrument for some petty purpose or passion.

Every Human Being is Entitled to the Best Possible Conditions of Life

It must be clear that great new realms of knowledge and power involve new moral problems; that is, indeed, the capital fact, the problem of problems, of our age. Our official moralists are still living in the past, and giving us dogmas instead of principles. In such a case those must teach who believe they can, whether they hold any office or none, and whatever the censure they may draw upon themselves.

We shall here, therefore, lay down the principle, old and new, that *the best possible nurture is none too good for any human being*. More and more this essential truth is becoming accepted. Aristocracy may wish to save a class, the Church may wish to save the elect from a lost world, but eugenics proposes to save the world. The Eugenist maintains that every human being who comes into existence is, by that fact, entitled to the best possible conditions for its nurture—according, of course, to the particular needs of its particular nature. Here is a fundamental moral principle; and there is no compromise possible, nor ever can

be, between those who accept it and those who reject it—nothing but ceaseless war until the triumph of the right. The instant that the conception of the two germ-cells has occurred, a new human life is in the world; and the very persistence of mankind is in danger if we relax the indefeasible rigour of the principle that that new life, and every existing life, at that and every subsequent stage, is entitled to the best nurture for its needs.

All New Life that Comes into the World must be Regarded as Sacred

The Eugenist sees, what no one else sees, that in only too many cases the new life should never have been made. He sees, and must teach the world, that its care and control must begin earlier than ever heretofore. He must repeatedly protest against the folly and carelessness which have permitted, say, the feeble-minded girl of sixteen to wander in the streets and be ruined, and help to ruin the future, after the daily fashion which disgraces all who know and do not protest against it.

But the principle here laid down is that, the instant a new life has been formed, and always thereafter, the claims of Natural Eugenics can no longer be heard in that particular case. The Eugenist should have spoken sooner, or, if he spoke and was not heard, he must register his protest, and now proceed to make the best of a bad business, saying, " I told you so," at every lamentable stage in the development and history of the half-witted or diseased child which the folly of society has brought into the world. But no matter what that new life may be, no matter how certain to be part not of the wealth but of the *illth* of the nation, no matter whether the invisible beginnings of its history are in a palace or a slum, or whether its parents be married or unmarried, that is a new human life in the world; it is therefore sacred, and entitled to whatever conditions will make of it the best that its nature makes possible.

The Lie that the Labour of a Mother in a Factory Does No Harm

Not by denying that will the Eugenist ever obtain the consent of public opinion to the merciful prevention of parenthood that can only result in offspring worthless to themselves and to others, hopeless and dangerous whatever nurture, whatever love and money and tears, be expended upon them.

Logically, nurture comes second in our study and our campaign, and that statement of its place is the distinctive mark of modern eugenics. Nevertheless, for several reasons we shall here deal with nurture or Nurtural Eugenics first, and with Nature and Natural Eugenics thereafter. The best of those reasons is that the demands of nurture are clear, requiring no previous research in genetics, and that public opinion already assents to the principle, and is seeking to apply it in many ways. Further, we must attempt to stem the flood of pseudo-eugenic literature with which the public in this country, though fortunately not in America or on the Continent, is being plied by the statisticians, to the effect that nurture is negligible, and in a lecture, not yet three months old, to the effect that the labour of a mother in a factory, rather than in her home, does no harm to her children.*

Here we find our analyses met with the old question, so familiar and so foolish: Which is the more important, heredity or environment, " nature or nurture " ? To the biologist, who sees both factors necessary for every tissue, organ, function, feature, of every living thing, the question is a futile one. There is no better illustration of the truth enunciated by Bacon, that the triumph of philosophy depends upon rightly putting the question to Nature.

The False Ideas about Heredity that are Taught To-day

If a living creature were made of a piece contributed by heredity, and a second piece manufactured from the environment, and stuck on to the first, the question could be asked and answered. If, for instance, a new cell grew into an adult by plastering its food outside itself, then we could say that such and such a percentage of its composition was due to nature, and such and such to nurture. But that is not what happens. Every iota of the organism is a product of multiplication, in which two factors, nature and nurture, are necessary, for we cannot multiply without two factors, and ten times nothing is not ten, but nothing.

Notwithstanding the simplicity of the facts, for many years past we have been taught on all hands, in many contradictory voices, that nature has an influence upon the individual equal to, say, 75 per cent., and nurture 25 per cent.—or the other way about. Both statements are equally wrong and equally right. When the mathematicians tell the public and the students of life that nature is more important than nurture, say, as regards longevity, the simple and final reply is —what nurture ? And a few drops of prussic acid in the calculators' soup, no matter how long-lived their ancestors, would demonstrate

in as many seconds that the question which they have forgotten to ask is the whole question. Large numbers of the community at the present day are subjected to the continuous action of all manner of poisonous influences, both before birth and after it. To assert the all-importance of nature or heredity without remembering that all our promise may be blighted by, say, the infantile diarrhœa of our large towns, is well-nigh to condemn eugenics in the eyes of rational men and women.

The Defective Nurture that Destroys 100,000 British Children Every Year

Every child needs nurture. Newton was a weakly baby, prematurely born, and would promptly have been condemned as not worth keeping had the statistical school been in power in his day. No one knows how many babies, of priceless possibility, like Newton's, have been destroyed since his day, and before it, by defective nurture such as now destroys a hundred thousand infants in these islands every year—infants most of them as viable at birth as we were, the more fortunate who read and write these lines. Here, then, we shall proceed to assert the claims of nurture for every new human life coming into the world; and those claims will only become more, not less, important the higher the quality of human material that may in the future be made available by Natural Eugenics, for the finer the hereditary possibilities, the more care will they need and repay, and the greater will be the loss if they do not receive it.

The exact meaning and limits of nature or heredity are definite; the limits of nurture or environment are infinite. The fact must never be forgotten. If we were merely discussing the amœba, we could limit environment or nurture to a few matters of water, salts, air, and the like. But if we speak of man we need to include not only everything whatsoever that is included under the nurture of the lower animals and the plants, but also a vast realm of influence to which man alone can respond.

The Ability of Man Depends Partly upon Heredity, but also upon Environment

The calculators speak of the inheritance of ability, and attempt to reckon the degree of its transmission, just as they reckon the transmission of eye colour; but while eye colour does not depend upon the books the eyes open upon, ability is perhaps not entirely unconnected with, say, learning to read, learning to learn, and with the question whether one feeds one's mind upon treasure or trash. Whenever we speak of nurture or environment, with reference to man, as meaning anything less than the whole environment, atmospheric, dietetic, microbic, social, spiritual, we are simply making the error of forgetting, in the first place, what man is and what man ought to be.

Man is immeasurably the most complex of all things. His ability, for instance, depends partly upon heredity—a momentous fact which the Eugenist remembers and weighs and teaches—but it also depends upon education and inspiration, and the presence of certain compounds in the diet, and the development of certain tiny glands in the body, the non-activity of the thyroid gland in the neck being alone sufficient to reduce any genius to idiocy and death. In the face of these elementary facts, familiar to every physiologist and doctor, the biometricians' assertion that the inheritance of ability can be reckoned like the inheritance of brown eyes is simply to be dismissed as ignorant. These writers need ten years' preliminary biology before they can usefully employ their mathematical equipment.

Great Moral and Psychological Factors that must be Considered

Then there is social psychology to reckon with also. A man's conduct and a man's collar-bone are not similarly determined. The nurture of a man includes public opinion, the power of personality, and the great factors of imitation, sympathy, and suggestion. Every man has seven vertebræ in his neck; there is no case on record of any other number, and no nurture that we can apply will alter the number. But a man's beliefs and a man's backbone cannot be suitably compared when we are discussing nature and nurture; and whatever induces or produces beliefs, influences conduct, and in part determines what the man is. Man has not only his physical heritage, but his social heritage, infinitely variable and fluctuating, immeasurably potent for good and for evil. We may present the mind of the adolescent boy with the printed wickedness or the printed nobility which are both part of our social heritage. The so-called eugenics which denies the difference and the consequence is not worth a sneer.

Evidently nurtural eugenics, thus adequately conceived as the sum of all the influences which make, mould, and modify man, must include, and does include, many sciences which require separate treatment. The science of health or hygiene, the science

of social forces, the science of education—all these discuss part of the nurture of man. The Eugenist claims them for eugenics, but he has not the folly to presume that he is therefore master of them, and can dictate to those who are. Here, in the name of eugenics, we do homage to them, honour them for their services to our cause, commend their study and application, and must then pass on to what may be called the nearer and more primary environment, which is neglected in many of its aspects, and looked at in others from another point of view than ours. Above all, in our study, we must insist upon beginning at the beginning, which is the expectant mother, as such eugenic races as the Jews have done, recognising for thousands of past years the importance of ante-natal nurture.

But if we are thus to subvert the order of time and causation, and are to take secondary before primary eugenics, dealing with expectant motherhood before asking ourselves whether those parents should ever have met, we must once and for all realise what are the limitations, set by natural necessity, to the power of nurture. Observe that we demand and mean to obtain the best, which means the most fitting, nurture for every new life. This is a great demand, and while we make it we require to qualify the hopes of those whom we desire to grant it. The best nurture is not too good for any human being; but the best and most suitable nurture, applied without exception to every new human life, will neither make all lives worthy nor will it effectively elevate the race except by teaching men wisdom enough to practise primary eugenics.

"THE PROMISE OF EDUCATION"—FROM THE GROUP ON THE GLADSTONE STATUE IN LONDON

Education, upon which it is true to say much depends, is not the cure for all our ills, as some suppose. Nature matters, too. It may be said that education is as much like the process of holding to the fire a paper already inscribed with invisible ink as it is like the writing of new characters. Education is both.

There are here two definite and all-important propositions, each of which must be verified. The first asserts sharp limits to the power of nurture for the individual, and the second asserts sharp limits to the power of nurture for the race. Let us take these in turn.

This is not the place in which to discuss the theory and practice of education, but it is the very place in which to assert that the form of nurture which we call education is sharply limited by the nature of the material educated, and further to assert that educators in the past and in the present have too often claimed for their great practice far more than it has ever achieved, or ever will achieve. Before the modern study of heredity, such great thinkers as Helvetius and Kant—and also Locke, who likened a child's mind to a smooth writing-tablet, or *tabula rasa*—seriously supposed, what many still suppose to-day, that the differences between men are due to differences in education. They did not realise that, as a modern student of education has admirably said: "The page of the youngest life is so far from being blank that it bears upon it characters in comparison with which the faded ink of palæography is as recent history." Education is as much, indeed, like the process of holding to the fire a paper already inscribed with invisible ink as it is a process of inscribing new characters upon the surface of the new mind. It is *both;* and this is the whole truth, of which we find it so difficult to appreciate both halves.

THE HARD LOT THAT DEPRIVES A VAST MULTITUDE OF THE BEST CONDITIONS OF LIFE

"HARD TIMES," FROM THE PICTURE BY PROFESSOR HUBERT HERKOMER, R.A., NOW HANGING IN THE MANCHESTER ART GALLERY

We make, of course, the most ridiculous claims for education, as for most other, if not all, forms and aspects of nurture. Byron was educated at Eton, and we say that Eton produced him, the real truth being, of course, that Eton failed to destroy him. If Eton produced him, and if Oxford produced Shelley, why does it not produce thousands like them? There is plenty of material, but it is not the right material. No polishing will make pewter into silver.

The Great Differences Between Men which Education Accentuates and does not Destroy

Nay, more: the real facts of education are just the opposite of what is supposed by those who regard it as the social and racial panacea. They think education is a levelling process. On the contrary, it accentuates the differences between men. We may confuse the unpolished pebble with the unpolished diamond, but not when education has done its best for both. This is the tremendous error, of which nearly all Socialists have been guilty hitherto, though one must admit, with gratitude and pleasure, that within the last few years the most thoughtful and influential Socialists have immensely strengthened their case by recognising the eugenic principle of the natural and ineradicable inequality of men, even though this doctrine exposes them to the rancour of those among their followers who most conspicuously illustrate it.

That towering and noble genius John Ruskin stated, forty years ago, in words absolutely verified by the conclusions of science to-day, the truth of this matter. Not being so foolish as to suppose that one can improve upon his statement, there is no choice but the excellent one of quoting it.

Ruskin's Exposition of the Fallacy that Education Solves the Problem of Inequalities

Education (said Ruskin) *was desired by the lower orders because they thought it would make them upper orders*, and be a leveller and effacer of distinctions. They will be mightily astonished, when they really get it, to find that it is, on the contrary, the fatallest of all discerners and enforcers of distinctions; piercing even to the division of the joints and marrow, to find out wherein your body and soul are less, or greater, than other bodies and souls, and to sign deed of separation with unequivocal seal. Education is, indeed, of all differences not divinely appointed, an instant effacer and reconciler. Whatever is undivinely poor it will make rich; whatever is undivinely maimed, and halt, and blind, it will make whole, and equal, and seeing. . . . But there are other divinely appointed differences, eternal as the ranks of the everlasting hills, and as the strength of their ceaseless waters. And these education does not do away with, but measures, manifests, and employs. In the handful of shingle which you gather from the sea-beach, which the indiscriminate sea, with equality of fraternal foam, has only educated to be, every one, round, you will see little difference between the noble and the mean stones. But the jeweller's trenchant education of them will tell you another story. Even the meanest will be the better for it, but the noblest so much better that you can class the two together no more. The fair veins and colours are all clear now, and so stern is Nature's intent regarding this that not only will the polish show which is best, but the best will take most polish. You shall not merely see they have more virtue than the others, but see that more virtue more clearly; and the less virtue there is, the more dimly you shall see what there is of it.

And the law about education, which is sorrowfullest to vulgar pride, is this—that all its gains are at compound interest; so that, as our work proceeds, every hour throws us farther behind the greater men with whom we began on equal terms. Two children go to school hand in hand, and spell for half an hour over the same page. Through all their lives, never shall they spell from the same page more. One is presently a page ahead, two pages, ten pages, and ever more, though each toils equally, the interval enlarges—at birth nothing, at death infinite.

Education that Acts as a Magnet in Separating the Gold from the Dross in all Classes

Those words were written in 1867, three years before the coming of popular education. They have been tested for a generation and found true. There has been a marvellous levelling of education, with the result that we find worthless trash and priceless treasure *in all classes*.

"Education has been put at the beginning, when it ought to have been put at the end. It matters comparatively little what sort of education we give children; the primary matter is what sort of children we have got to educate." So said a great student, Dr. Havelock Ellis, forty years after Ruskin. Neither education, then, nor any other form of nurture can alone achieve the eugenic ideal. No matter how good our polishing, we must have silver and diamonds to work upon, not pewter and pebbles.

This principle need not further be amplified; but if a recent and striking illustration of it be demanded, we may cite the case of the new schools for mentally defective children which were started in this and other countries with such high hopes that special care and skill would bring these children up to the normal standard of intelligence and conduct. Admirable and necessary as these schools are, they are in no respect more useful than in teaching all

and sundry, as they now do, that education develops but cannot create.

But though the partisans of nurture in all its forms may be nonplussed by such demonstrations as modern education has afforded, they still have another and most important argument; and that involves us in the second proposition regarding the limits of nurture. It is supposed that if we educate the parents the child will begin where the parents left off. This assertion is notoriously contrary to the facts of every day. It depends upon the belief that the effects of use and disuse are transmitted to offspring, a belief which is at all times contradicted by the scantiest observation, but which becomes a complete obsession when we find it used for partisan purposes.

Thus the advocates of votes for women —as to which nothing is here said for or against—declare that the political incapacity of women, alleged by their opponents, is due to ages of disuse, and cannot be recovered at once. This ridiculous but familiar argument assumes not merely that the effects of disuse are transmitted to offspring, but that they are exclusively transmitted to offspring of the same sex as the parent, it being forgotten that mothers have sons as well as daughters, and fathers have daughters as well as sons.

The Efficiency that a Man can Never Transmit to His Children

Neither the effects of use nor of disuse of any organ or faculty of the parental body are transmitted to the offspring. The subject has been carefully studied for decades, by all manner of means, and the fact has long ago been proved. It follows that all those forms of nurture, education, or "the provision of an environment," as we shall here define education, which involve no more than the use, practice, or development of particular functions or organs, are impotent as regards the race. They serve individuals, which is their abundant justification, notwithstanding the limits imposed, as we have already seen, upon that service. But they do not serve the race; and half the disappointments and failures of history are due to the delusion that they do.

If the old view were true, as Lamarck supposed it was when he based a theory of evolution upon it, the provision of good nurture would be a completely adequate instrument of eugenics, and what we have called primary or natural eugenics would be superfluous. Even though good nurture would not reform the world in a single generation, owing to the individual limitations imposed by the nature of the material, yet in each successive generation, on this view, the material would improve inherently, and by a kind of snowball process man would climb rapidly starwards. The good habits acquired, perhaps with pain and labour, by one generation would be innate, natural, inevitable in the next. Our parents' nurture would become our nature, "my father's environment would be my heredity." We should not need to discuss any question of selection for parenthood. Without any such process we could raise the race at once, as one storey of a building is built upon another.

The Great Heritage that can Come Down Only Through Society

Nothing of the sort happens. The results of education, physical, mental, or moral, are confined to the individuals educated. The personal acquirements of one generation, in speech or muscular development or information, die with their possessors. The children do not begin where the parents left off, but they make a fresh start where the parents did. The social heritage may be improved by the parents' doings: in this sphere, thank Heaven and man's power of recording his achievements, there *is* "transmission of acquired characters," or where should any of us be? But the germplasm of the individual who learns ten languages remains what it would otherwise have been, and his subsequent child, formed therefrom, has to begin at *a, b, c* like his father. True, the child may be a good linguist, but that is evidently because it has inherited the natural linguistic capacity which was inherent in its parent, and has had, probably, the further advantage of being brought up in a linguistic home.

The Good Nurture that at least Protects the Nature of the Next Generation

We proceed, then, in our study of nurture and our demands for its granting to every human life, but all the while we must steadily remember that what we ask for will never rightly repay us until the demands of primary or natural eugenics have been satisfied, and good nurture has nothing but good material to work upon.

Lastly we note, however, that in certain special and well-defined cases our nurture is equivalent to protecting the nature of the next generation. These are the cases of the racial poisons, which can poison the germ-plasm if they enter the body of a future parent. The good nurture which protects the body from these forms of malnutrition is thus of unique importance.